Instruments

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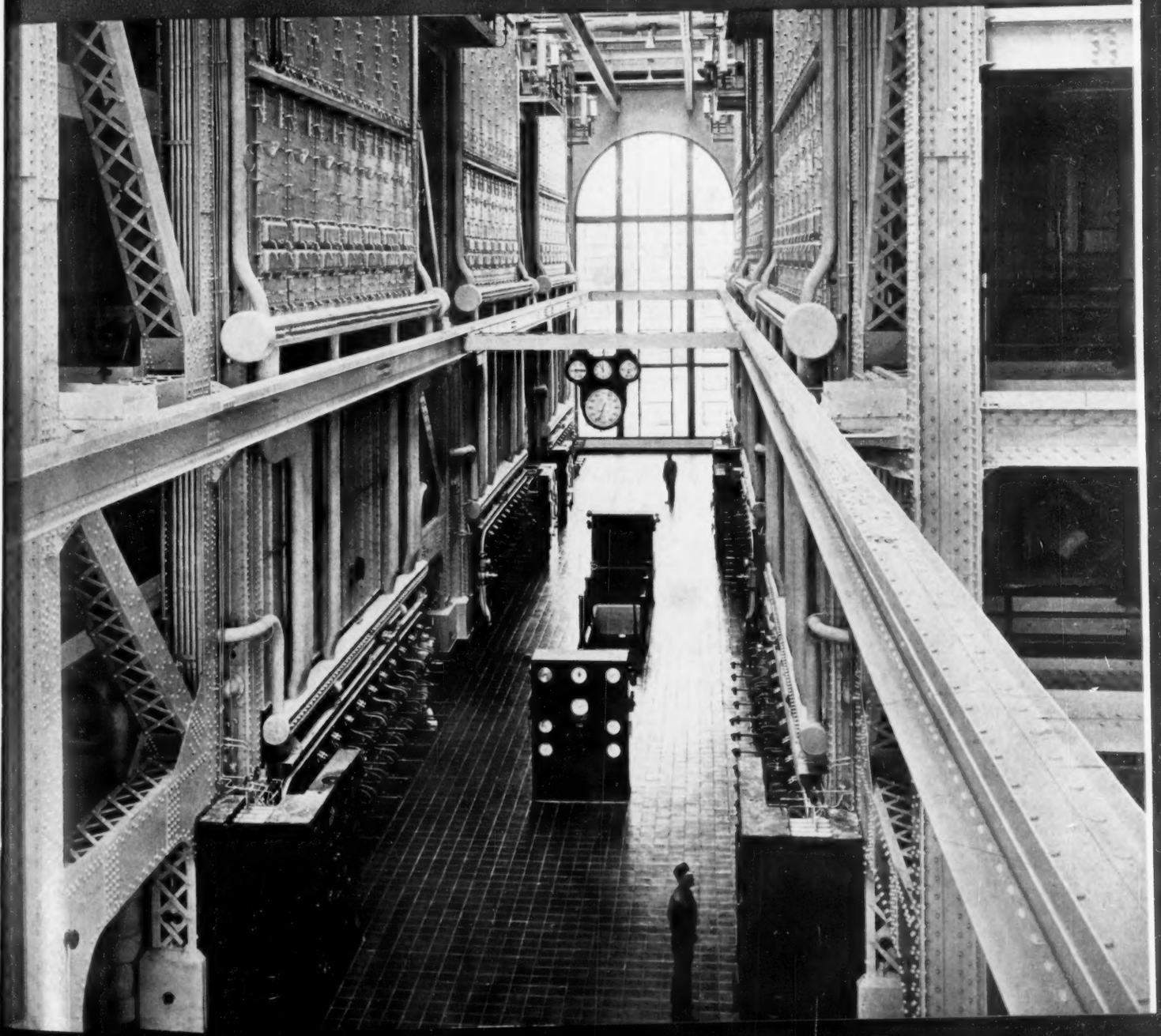

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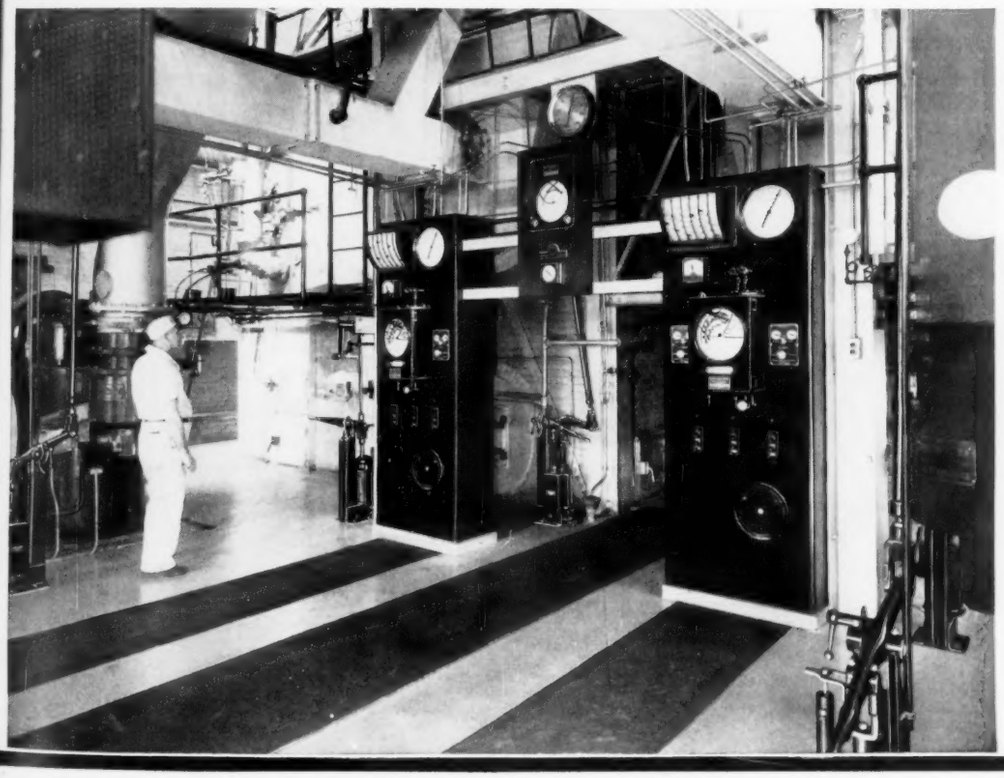

Mr. John Dobson, Chief Engineer, watches Bailey Meter Control carry the Sucrest Refinery load at Test Efficiencies.

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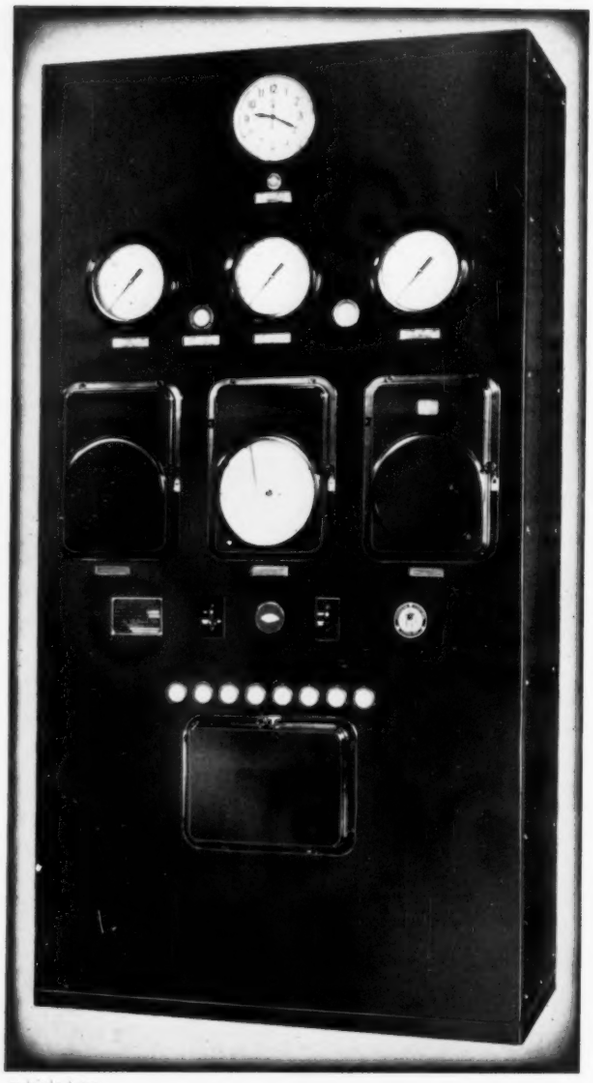

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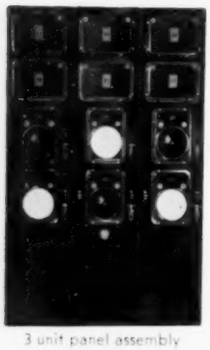

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THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 No. 10

OCTOBER, 1938

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EDITORIAL COMMENT 227

AUTOMATIC COMBUSTION CONTROL SYSTEMS

System	*Author*	
ASKANIA	H. Ziebolz	228
BAILEY	H. M. Hammond	230
BRISTOL	O. J. Leone	232
BROOKE	J. S. Merritt, Jr.	234
BROWN	H. M. Schmitt	236
CASH	J. J. Klinker	237
D.F.C.	Frank Gawan	238
DEXTER-GOEBEL	E. F. Goebel	240
G-E	H. M. Webber	241
HAGAN	T. A. Peebles	242
HAYS	W. H. Pugsley	244
METERMAX	E. S. Bristol	246
JOHNSTON	E. L. Kroon	248
R-K	Linwood Kimball	249
SHALLCROSS	Carl Schindler	250
SMOOT	Chester Earle	251
WESTINGHOUSE	C. E. Peck	254

INSTRUMENTATION CONTEST 255

NEW INSTRUMENTS 256
Indicators, recorders, controllers, inspection devices, etc., for plant, field and laboratory

INSTRUMENTS' BOOK SHELF 266

MANUFACTURERS' NEW LITERATURE A11

ADVERTISERS' INDEX A12

BUYERS' GUIDE A13

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Instruments

THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Combustion Instrumentation

IN this special issue, automatic combustion control systems are described—each by an engineer associated with its development. You will discover with pleasure that these descriptions are concise, clear and—with regard to basic principles—comprehensive. The authors (and several behind-the-scenes assistants with a flair for presentation) deserve Industry's thanks.

Now, then, how many combustion control systems do you think there are? . . . So did we, up to last summer: we thought that there were more than fifty manufacturers of miscellaneous combustion control devices but fewer than a dozen "full-automatic" systems. You will find, on pages 228-254, seventeen different makes of automatic systems.

This symposium was first planned several years ago and definitely decided upon one year ago. Last May we sent formal invitations to thirty-three manufacturers, and since then to four more—to a total of thirty-seven whom we found in all sources of information known to us.

37—17—20, but this does not mean that we rejected twenty manuscripts. There are only two real absentees: one firm, new in the field, is not ready to publicize its system; the other, old in the field, doesn't want to publicize its old system because it is developing a new one. A majority of the other eighteen replied that they did not manufacture "automatic combustion control systems"—and only a minority sent us manuscripts in good faith—in the belief that their products qualified. Only in the case of this minority were the descriptions "rejected"—not arbitrarily but because the products described did not qualify as "automatic" or as suitable for "combustion" control or as a "control system." The authors themselves found these reasons for rejection to be valid because based on simple definitions, the liberality of which is self-evident:

In the first place, we did not limit "combustion" to steam-boiler furnaces: we threw our columns open to descriptions of all systems for the automatic control of *the combustion process* wherever this process finds industrial applications.

Even our most rigid requirement—automaticity—is so simple that there can be no two ways of looking at it: if a system does not command a valve, rheostat, damper, etc., in order to hold at least one combustion condition at a predetermined value, it obviously isn't automatic. The most wonderful array of autographic recorders, automatic gas analyzers, etc., isn't automatic control. Neither is a system of the most modern remote controls which are manually commanded.

Then, too, a system equipped to control the combustion process must naturally start with a measuring element responsive to a utilizable effect of this process.

(It is to the credit of some manufacturers of draft regulators whose names appeared under "Combustion Control" on various lists we used, that they saw this point and told us that they did not qualify.)

Finally, the system must be for combustion control—not for the control of room-temperature or other indirect use of B.t.u's.

(And it is to the credit of manufacturers of thermostats, time switches, etc., whose names appeared under "Combustion Control" on various lists we used, that they saw this point and told us that they did not qualify.)

The articles on the following twenty-seven pages have been boiled down to *descriptions*. In so doing we had to strike out some interesting dissertations on the benefits of combustion control. It had to be done, because most of these dissertations, being general, repeated one another. That was particularly true of the manuscripts on boiler-furnace combustion control systems. In the case of other applications, we left standing several sentences not purely descriptive of the control systems but definitely pertinent.

After reading all articles, the conclusion which inevitably emerges is that automatic combustion control has definitely become a branch of Instrumentation. Nine of the seventeen systems described on the following pages were developed and are made by firms definitely classifiable as instrument-makers; five of the eight others are products of the instrument-making departments of diversified manufacturers.

Not many years ago, an acquaintance of ours who makes combustion control systems begged us not to call him an instrument manufacturer because he thought it would hurt his sales among power plant men who—he thought—wanted "heman systems, not delicate instruments." We believe that most combustion engineers among our readers will take the opposite view—if not offhand, then after reading the following pages. They will want modern instrumentation jobs, knowing that industrial instrumentation combines laboratory accuracy with machine ruggedness.

Automatic combustion control is Combustion Instrumentation!

AUTOMATIC COMBUSTION CONTROL SYSTEMS

INDEX

A-Jacks 236
Askania Regulator Co.....228
Bailey Meter Co.....230
Bristol Co. 232
Brooke Engineering Co.....234
Brown Instrument Co.....236
Carrick 244
A. W. Cash Co.....237
D.F.C. 238
Denver Fire Clay Co.....238
Dexter-Goebel 240
G-E 241
General Electric 241
Hagan Corp. 242
Hays Corp. 244
Johnston Mfg. Co.....248
Leeds & Northrup Co.....246
Metermax 246
Minneapolis-Honeywell Reg. Co.....236
National Brass Co.....240
National Regulator Co.....236
R-K 249
Republic Flow Meters Co.....251
Ruggles-Klingemann Mfg. Co.....249
Shallcross Controls, Inc.....250
Smoot 251
Valveless 248
Westinghouse Elec. & Mfg. Co.....254

The Askania System

By H. ZIEBOLZ

Vice-Pres., Askania Regulator Co.

SINCE combustion control represents one special field within the large province of automatic proportioning, Askania combustion control systems are made up chiefly of standard Askania automatic ratio control elements. Only the principles will be described in this article. For brevity's sake, no construction details will be gone into. For simplicity's sake, all diagrams but the last will show orifices representing gas and air flow measurements.

The usual purpose of automatic combustion control is to establish a desired ratio between fuel and air. This ratio can be maintained constant for different rates of flow or can vary as a function of the primary flow or proportionally to another variable, which in turn is a function of this ratio. (For example, superimposed correction by the CO_2 content of the products of combustion.)

The basic form of a combustion control is a flow control, the setting of which is varied in relation to another variable. Fig. 1 shows the control unit A which responds to the flow through line 1 as metered by the orifice and which positions a piston P in direct proportion to the flow across the orifice plate in line 1. By means of a cam and an adjustable spring the regulator unit B, which represents the flow control governing the rate of flow through line 2, is reset in accordance with the rate of flow in line 1. Evidently any ratio between the two flows can be obtained by proper cam shape.

If the two differential pressures are to be directly proportional to each other, it is possible to eliminate A and apply the differential pressure obtained from the orifice in line 1 directly to balance the differential pressure in line 2. See Fig. 2. As both differentials change with the second power, the maintenance of a constant ratio between them will mean a constant ratio between the respective flows.

An Askania ratio slider, Fig. 3, built between the two diaphragms together with a second lever, permits a 12-to-1 range of adjustment of the ratio between the two differential pressures.

For such a control system to function properly at low rates of flow, it must be extremely sensitive to small variations in both of the measured differentials, since these change with the second power of the rate of flow. If, for instance, the maximum differential is 1″ of water, the impulse at 10% flow will drop to 0.01″. An error of 0.01″ will then amount to about 40% error in flow.

For wider ranges, instead of utilizing constant-area orifices with variable differentials, the controls embody variable-area orifices with a constant pressure drop across each orifice. Butterfly valves calibrated through a certain range of

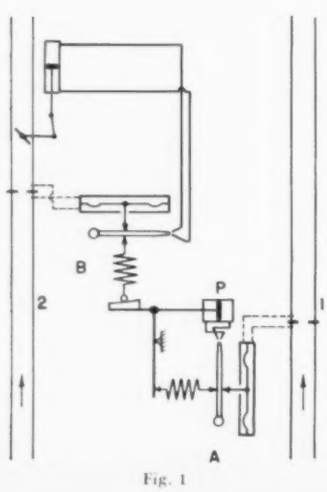


Fig. 1

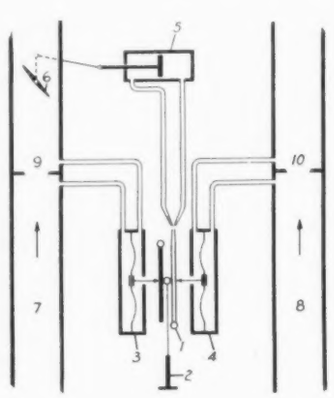


Fig. 2

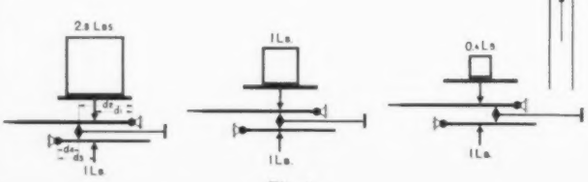


Fig. 3

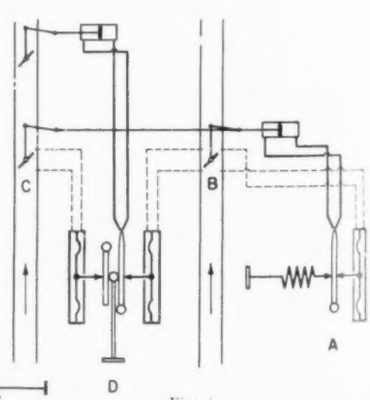


Fig. 4

movement may be used as variable orifices. In Fig. 4 regulator A maintains a constant differential across butterfly B. The position of butterfly C varies in direct proportion to the movement of butterfly B. The ratio regulator D maintains the ratio of differentials across the variable orifices. Such an arrangement permits (with the necessary precautions with regard to Reynolds numbers) comparatively wide ranges for the flow rates of the ratio control.

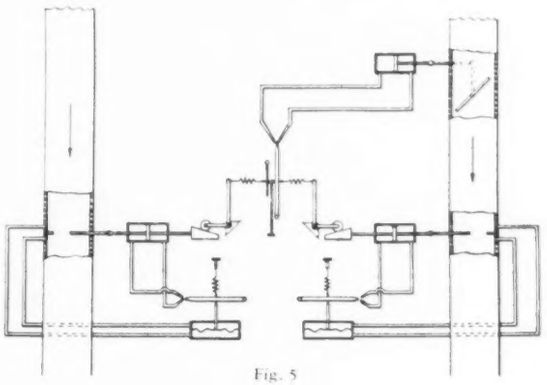


Fig. 5

It is possible to go one step further and provide two independent variable orifices using their positions as a means of measuring the respective flows. Such a layout covers any desired range and any specified ratio of fuel to air as a function of the rate of flow of either one of the variables. (Fig. 5) It has the further advantage of possible power savings as the differential pressures (energy loss) at higher rates of flow are small fractions of the drops produced by fixed orifices.

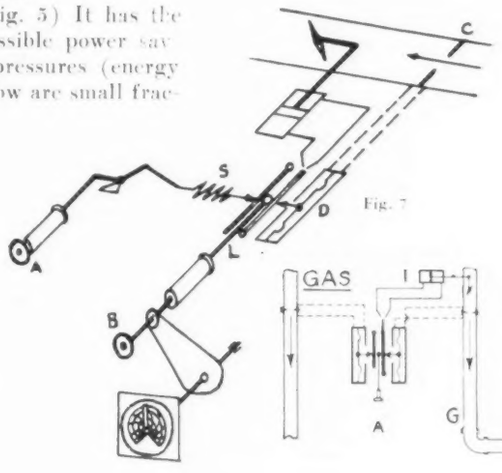


Fig. 7

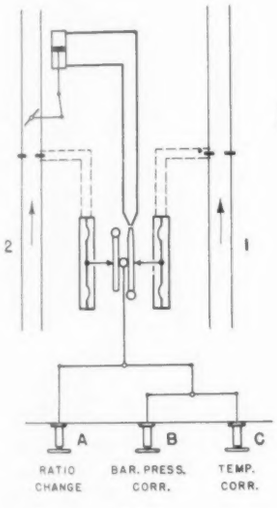


Fig. 6

All above systems are, strictly speaking, ratio controls of differential pressures. In practice we meet variations in the temperatures and pressures of the gaseous fuels, in the viscosity of oil, or in the B.t.u. content of coal or gas, so that correction factors have to be introduced to compensate for these variables. In the above systems the necessary correction factors are simply applied by an adjustment of the ratio slider. This slider adjustment multiplies the ratio of the opposing forces by a definite factor. Due to the logarithmic characteristic of the Askania ratio slider arrangement, a plurality of correction factors can be introduced by merely adding logarithmically calibrated movements. Fig. 6 shows the principle: changes of adjustment of A, B, and C determine the value of the sum of the factors by which the flow differentials are multiplied.

In combustion control problems the perfect solution calls for controlling the ratio of weight of oxygen to weight of gas, rather than the ratio of volumes, so that barometric pressure and temperature corrections have to be introduced when utmost accuracy is required. In the actual instrument the corrections for barometer and temperature are usually combined in one scale. (Fig. 7.)

Another problem is the automatic change of the ratio setting to compensate for changes in B.t.u. or density or both simultaneously. A typical installation calls, for instance, for the use of different fuels for the same burners. To compensate for changes in density and B.t.u. and air requirement two main methods are used:

(1) Resetting of the individual controls either automatically or by hand.

(2) Central mixing station pre-mixing air and fuel to avoid resetting of the individual controls.

Each of the foregoing cases was a one-fuel problem. The plurality of fuels used in present industrial applications demands, however, a system to proportion total air regardless of fuel variations. The method used is shown in Fig. 8. Each individual fuel is measured; and its rate controls by means of a standard ratio control a secondary pilot flow of air (G, O and C in Fig. 8) which represents the air necessary for its combustion. The total of these representative flows controls the total air flow to the burners by means of ratio control N.

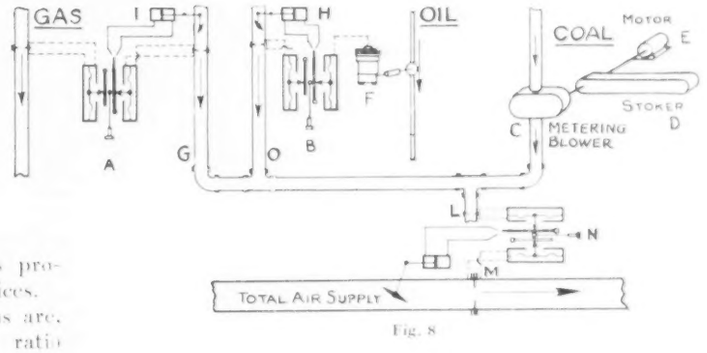


Fig. 8

Among other special problems solved by combinations of these elements are: (1) to maintain a constant heat input in B.t.u. hr. regardless of individual fuel flow variations; (2) to limit the supply of one or the other fuel to predetermined rates, allowing only limited static pressure drops in the supply lines; (3) to switch automatically from one fuel to another in case of deficiency of either one.

The choice of metering devices to obtain flow measurement indications for combustion controls depends on conditions. For air flow in pipes, orifices and flow nozzles are used. For combustion air in steam generators, boiler draft drop. On stokers of various types, the speed of travel is commonly used as indication of the amount of fuel fed to the boiler. Coal supplied by pulverizers can be measured by orifice plates in the primary air line by the feeder knife position or the feeder speed. For oil flow, orifices of the fixed or variable type, or the recently-developed Askania Transometer (F in Fig. 8) connected to a positive displacement meter. This device is used when it is desired that the accuracy of oil flow indications be unaffected by changes in viscosity, temperature and specific gravity.

The Bailey Meter System

By H. M. HAMMOND

Mgr. Sales and Engineering, Bailey Meter Co.

IN the Bailey Meter Company's system of automatic combustion control the outstanding feature is that it incorporates a Bailey steam flow-air flow meter* which makes the necessary readjustment in fuel or air automatically and continuously.

In the case of fuels burned on stokers, the boiler meter is incorporated in the system to automatically readjust stoker speed, thereby controlling fuel feed. In the case of fuels burned in suspension, such as pulverized coal, oil and gas, the boiler meter is arranged to automatically readjust the air supply.

Fig. 1 shows a typical application of Bailey Meter control to a large high-pressure boiler. This particular drawing represents the application of combustion control, superheat control, and three-element feed water control to two 1350-lb. pressure, 400,000-lb. /hr. capacity, 935° F. pulverized coal-fired boilers at the Rivesville Station of the Monongahela West Penn Public Service Co.

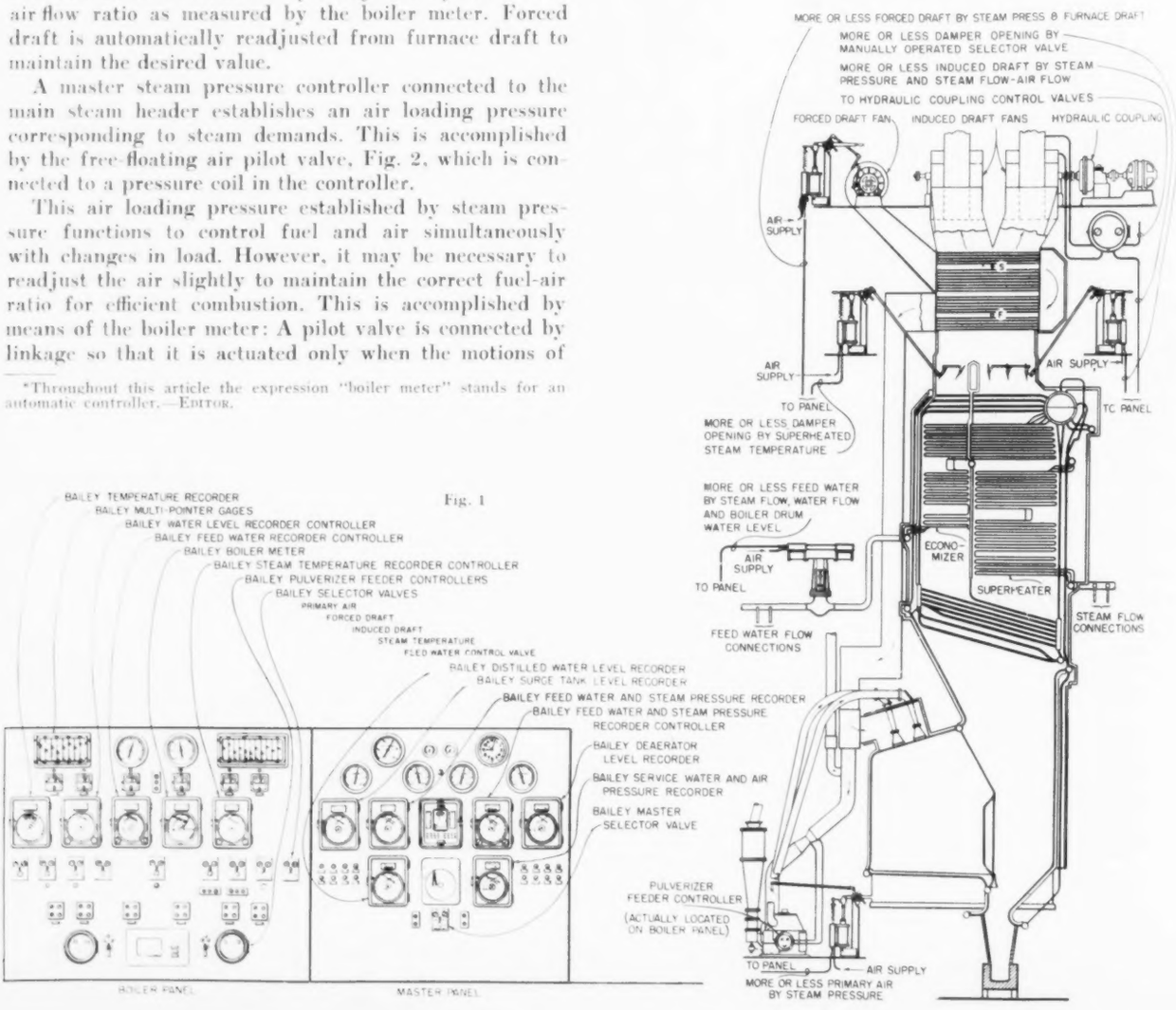
As indicated on the layout, fuel feed and induced draft are controlled simultaneously from steam pressure. Induced draft is automatically readjusted by steam flow-air flow ratio as measured by the boiler meter. Forced draft is automatically readjusted from furnace draft to maintain the desired value.

A master steam pressure controller connected to the main steam header establishes an air loading pressure corresponding to steam demands. This is accomplished by the free-floating air pilot valve, Fig. 2, which is connected to a pressure coil in the controller.

This air loading pressure established by steam pressure functions to control fuel and air simultaneously with changes in load. However, it may be necessary to readjust the air slightly to maintain the correct fuel-air ratio for efficient combustion. This is accomplished by means of the boiler meter: A pilot valve is connected by linkage so that it is actuated only when the motions of the steam flow and the air flow pens are not of equal amount. As long as the records coincide and do not separate the pilot valve remains in a neutral position. Should the air flow record rise above the steam flow record, indicating too much excess air, the steam flow-air flow pilot valve will move slightly, thus changing the loading pressure sent to an averaging relay, Fig. 3. This relay is so designed that the pressure sent out by it to the uptake draft control drive is the algebraic sum of the loading pressures received from the master pilot valve and the steam flow-air flow pilot valve. Therefore, any changes in loading pressure sent out by the steam flow-air flow pilot valve will bring about a readjustment in the position of the uptake draft control drive and bring the steam flow-air flow pens of the boiler meter back together for the desired combustion conditions.

The averaging relay is so designed, however, that the loading pressure from the steam flow-air flow pilot valve is throttled through a bleed valve so that its effect on the relay is slower than the effect of the loading pressure

*Throughout this article the expression "boiler meter" stands for an automatic controller.—EDITOR.


BAILEY TEMPERATURE RECORDER
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BAILEY FEED WATER RECORDER CONTROLLER
BAILEY BOILER METER
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BOILER PANEL
MASTER PANEL
MORE OR LESS FORCED DRAFT BY STEAM PRESS & FURNACE DRAFT
MORE OR LESS DAMPER OPENING BY MANUALLY OPERATED SELECTOR VALVE
MORE OR LESS INDUCED DRAFT BY STEAM PRESSURE AND STEAM FLOW-AIR FLOW
TO HYDRAULIC COUPLING CONTROL VALVES
FORCED DRAFT FAN
INDUCED DRAFT FANS
HYDRAULIC COUPLING
AIR SUPPLY
AIR SUPPLY
AIR SUPPLY
TO PANEL
TC PANEL
MORE OR LESS DAMPER OPENING BY SUPERHEATED STEAM TEMPERATURE
MORE OR LESS FEED WATER BY STEAM FLOW, WATER FLOW AND BOILER DRUM WATER LEVEL
AIR SUPPLY
TO PANEL
ECONOMIZER
SUPERHEATER
STEAM FLOW CONNECTIONS
FEED WATER FLOW CONNECTIONS
PULVERIZER FEEDER CONTROLLER
(ACTUALLY LOCATED ON BOILER PANEL)
TO PANEL
AIR SUPPLY
MORE OR LESS PRIMARY AIR BY STEAM PRESSURE

Fig. 1

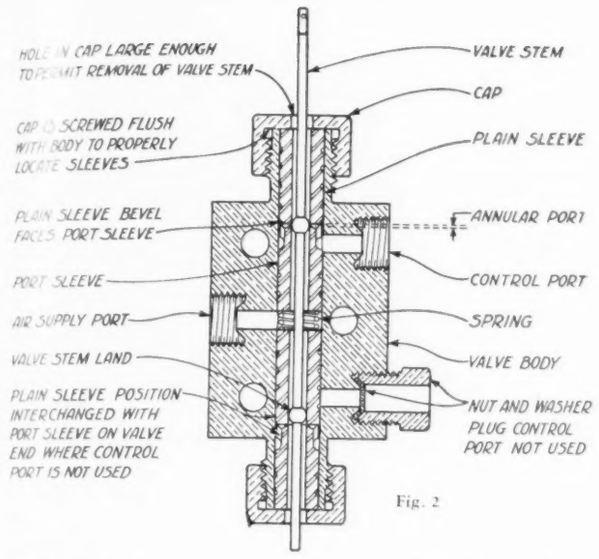

HOLE IN CAP LARGE ENOUGH TO PERMIT REMOVAL OF VALVE STEM
CAP IS SCREWED FLUSH WITH BODY TO PROPERLY LOCATE SLEEVES
PLAIN SLEEVE BEVEL FACES PORT SLEEVE
PORT SLEEVE
AIR SUPPLY PORT
VALVE STEM LAND
PLAIN SLEEVE POSITION INTERCHANGED WITH PORT SLEEVE ON VALVE END WHERE CONTROL PORT IS NOT USED
VALVE STEM
CAP
PLAIN SLEEVE
ANNULAR PORT
CONTROL PORT
SPRING
VALVE BODY
NUT AND WASHER PLUG CONTROL PORT NOT USED

Fig. 2

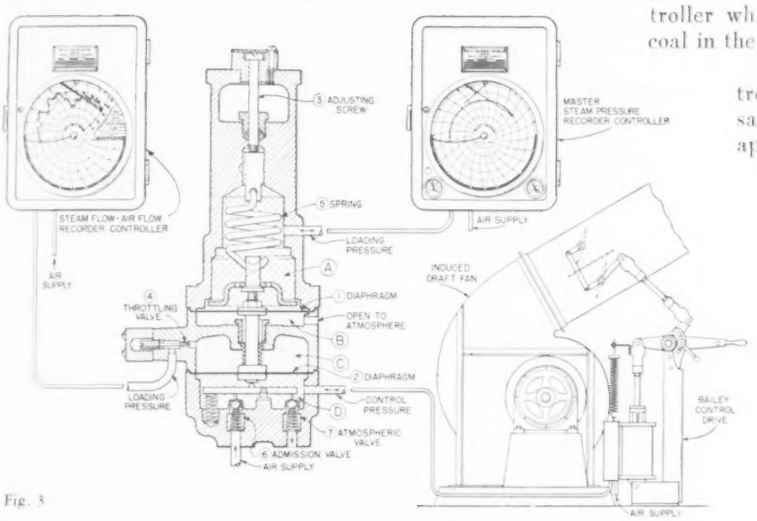


Fig. 3

from the master steam pressure controller. This gives the master pressure controller precedence over the steam flow-air flow readjustment.

At the Rivesville Station, control of induced draft is accomplished through the regulation of fan speed alone. Constant-speed motors are connected to the fan by variable-speed couplings manufactured by the Hydraulic Coupling Corp. Fig. 4 shows the arrangement of control equipment for regulating the amount of oil in the hydraulic coupling and thereby controlling the speed of the fan. The flow of oil to and from the hydraulic coupling is controlled by Bailey diaphragm-operated valves 1 and 2, responding to air pressure established by the control equipment. Valves 1 and 2 are closed as long as the coupling produces the desired output speed. Valve 1 opens to decrease the speed and valve 2 opens to increase the speed.

For proper control of a coupling driving a fan, it is necessary to maintain the fan speed directly proportional to the control loading pressure. This result is obtained by connecting the large diaphragm of the fan speed controller across the fan or boiler to measure air flow or gas flow and the metal bellows is connected to the control loading pressure. The forces produced by the diaphragm and the bellows are balanced against each other and as long as they are equal the air pressure applied to valves 1 and 2 keeps these valves closed, maintaining the oil content of the coupling constant. An increase in control loading pressure expands the metal bellows to the left and causes the air pilot valve to reduce the air pressure applied to valves 1 and 2, causing valve 2 to open and increase fan speed. The fan speed will continue to increase until the change in controller diaphragm force produced by the increased air flow or gas flow balances the increase in force produced by the metal bellows. This results in a fan speed proportional to the intensity of control loading pressure. A reduction in fan speed is obtained by decreasing the control loading pressure and opening valve 1.

As will be noted from Fig. 1, fuel feed to the boiler is controlled by regulating a damper in the primary air supply to the pulverizer in accordance with changes in steam pressure. The rate of raw coal feed to the pulverizer is controlled by the Bailey pulverizer feeder controller which operates to maintain the desired level of coal in the pulverizer.

Although Fig. 1 shows the application of control to a large central station type boiler, the same system of air-operated control has been applied to many small boilers ranging from 10,000 lbs./hr. capacity upward.

In addition to combustion control the diagram illustrates the application of Bailey three-element feed water control, which maintains the flow of feed water to the boiler equal to the steam output from the boiler and compensates for the effect of "swell" and "shrinkage" after load changes by the use of a boiler water level recorder. The drawing also illustrates the control of gas by-pass dampers for the maintenance of a constant superheated steam temperature.

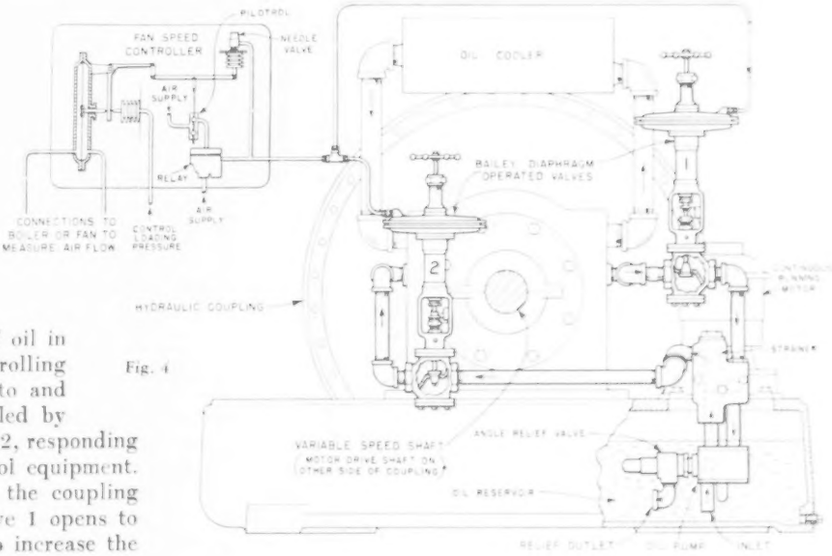


Fig. 4

For the sake of brevity, the above presentation has not included even bare mentions of numerous other instrumentation products of the Bailey Meter Co. which, as combined in various types of industrial installations, constitute an indefinite number of diversified automatic combustion control systems.

The Bristol System

By OTTO J. LEONE
Engineer, The Bristol Co.

IN this article are described some of the methods used by one instrument manufacturing company to adapt its standard line of instruments to industrial furnace combustion control applications. At the outset it may be well to point out some of the requisites of a combustion controller for industrial furnaces. First, the measuring system must be sensitive to small changes in the controlled condition, and at the same time accurately meter out to the dampers, etc., impulses which may be of small magnitude. Second, in order to transform these feeble impulses into forces adequate to accurately govern the process, it is essential that a control relay be used which will operate without friction and without in any way retarding the motion of the measuring element. Third, a controller should be flexible enough to make it adaptable to the characteristics of the condition or process being controlled, as for example by incorporating such features as adjustable throttling range and adjustable rate of automatic reset.

Fig. 1

The Free-Vane system of air-operated control, which meets the above requirements, represents one method of satisfactorily accomplishing automatic control. It is available in three types:

(1) Standard, with narrow throttling range;

(2) Ampliset, with adjustable sensitivity and throttling range;

(3) Reset, which incorporates adjustable throttling range and automatic reset of control point.

The essential parts of a free-vane system, such as the Reset type of which the instrument proper is shown in Fig. 1, are as follows:

(1) A measuring system which responds to changes in the controlled condition;

(2) A relay valve which permits air to pass to or from the controlled unit as commanded by the control unit;

(3) A free-floating vane which governs the air pressure supplied to the controlled unit;

(4) An air-operated motor unit which regulates the controlled condition;

(5) A control index for setting the control point.

The above are in all free-vane controllers. The Ampliset type has also:

(6) An adjustment of the lever ratio between the measuring element and the free vane, whereby: (*a*) after the controller has been installed and while it is in operation, the operator can adjust the relation between unit change in controlled variable and percent change in air to air-operated unit; (*b*) the controller can be made direct- or reverse-acting.

The Reset type illustrated in Fig. 1 embodies, as its designation implies:

(7) An anti-hunting feature, designated by various terms in technical literature but usually called automatic reset, and "officially" defined as follows: "An automatic mechanism which temporarily modifies the relation between measuring element and relay, which comes into play only while the controlled variable is changing, which proportions its corrective action to the rate of such change and which raises or lowers the point of balance in accordance with increases or decreases in process demand." Also:

(8) A means whereby the speed of this automatic-reset action can be adjusted after the controller has been installed and while it is in operation.

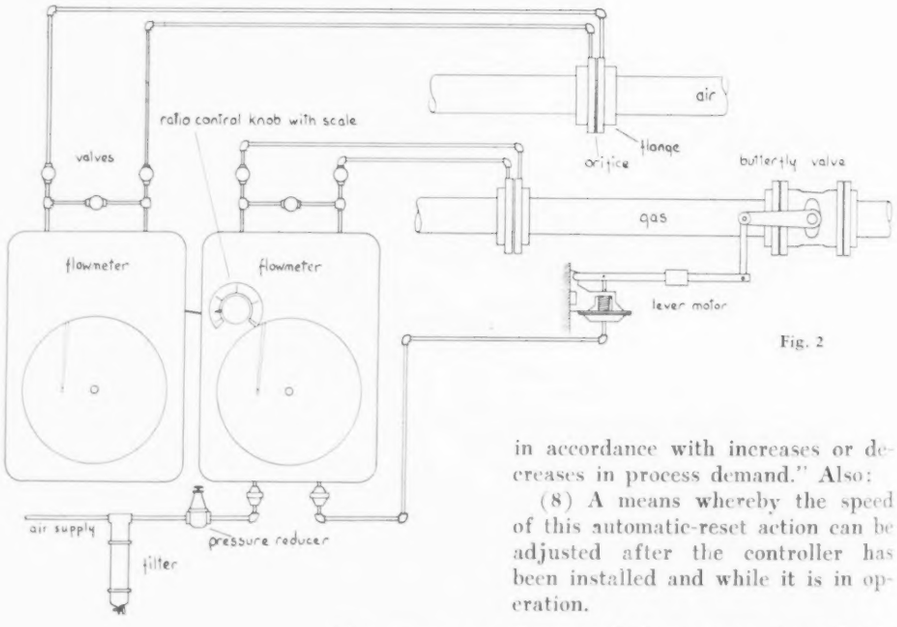


Fig. 2

The measuring element which actuates the pilot or relay may be of any form, from a relatively powerful Bourdon tube to a relatively feeble diaphragm, float, electric-instrument movement, etc., since its only control function is to position a vane which at no time is subjected to any torque.

Fig. 2 shows the arrangement used to control flow ratio between two fluids, such as fuel and air. Two flowmeter bodies which measure the differentials across orifices in each of the fluid lines are connected together by a ratio link. A free-vane system in one of the cases maintains the ratio set on a graduated dial.

Where scaling of the work in an industrial furnace must be prevented, the ratio controller shown in Fig. 2 is used to control the composition of the furnace atmosphere. In order to take care of the wide ratio ranges used with different materials, the fuel-air ratio is adjustable from 1-1 to 1-20. On certain steels, 1 volume of natural gas to 3 volumes of air is used; for bluing of steel, slightly higher ratios; but bright annealing copper, where too low a ratio would cause pitting of the work, demands almost the 1-11 ratio required for complete combustion of natural gas.

Fig. 3 shows a low-range draft or furnace pressure control system. The measuring element is essentially a highly sensitive differential-pressure bell float sealed in oil. A specially designed flexible stuffing box seals the upper part of the meter above the bell float and offers no resistance to the float movement. Since the free vane which is direct-connected to the pen mechanism requires no power to move it, the motion of the float is not retarded; this is desirable for furnace pressure control because the pressure in many cases must be controlled to within 0.002" of water. The low-range draft controller may be used with slide dampers, butterfly valves or louvers in the stack; or to control fan speed.

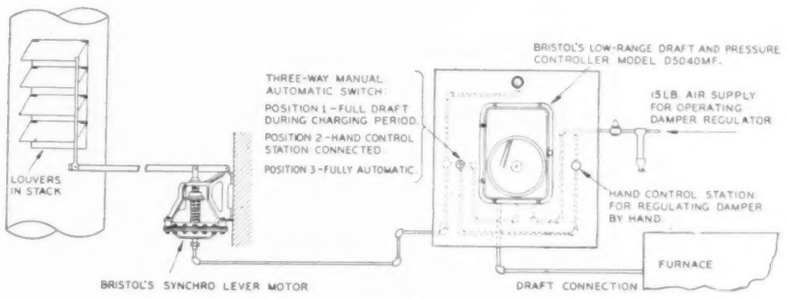

BRISTOL'S LOW-RANGE DRAFT AND PRESSURE CONTROLLER MODEL D5040MF.
THREE-WAY MANUAL AUTOMATIC SWITCH:
POSITION 1 - FULL DRAFT DURING CHARGING PERIOD.
POSITION 2 - HAND CONTROL STATION CONNECTED.
POSITION 3 - FULLY AUTOMATIC.
15 LB. AIR SUPPLY FOR OPERATING DAMPER REGULATOR.
LOUVERS IN STACK
HAND CONTROL STATION FOR REGULATING DAMPER BY HAND.
FURNACE
BRISTOL'S SYNCHRO LEVER MOTOR
DRAFT CONNECTION

Fig. 3

Fig. 4 shows the layout of a recent open-hearth control installation. The following factors are measured and controlled:

(1) Fuel and air are metered, recorded, and a definite fuel-air ratio is maintained.

(2) A low-range reset draft controller maintains constant furnace pressure by means of draft regulation.

(3) An Ardometer radiation pyrometer sighted on the inside of the roof limits the rate of heat input so as to prevent roof brick failures due to excessive temperatures.

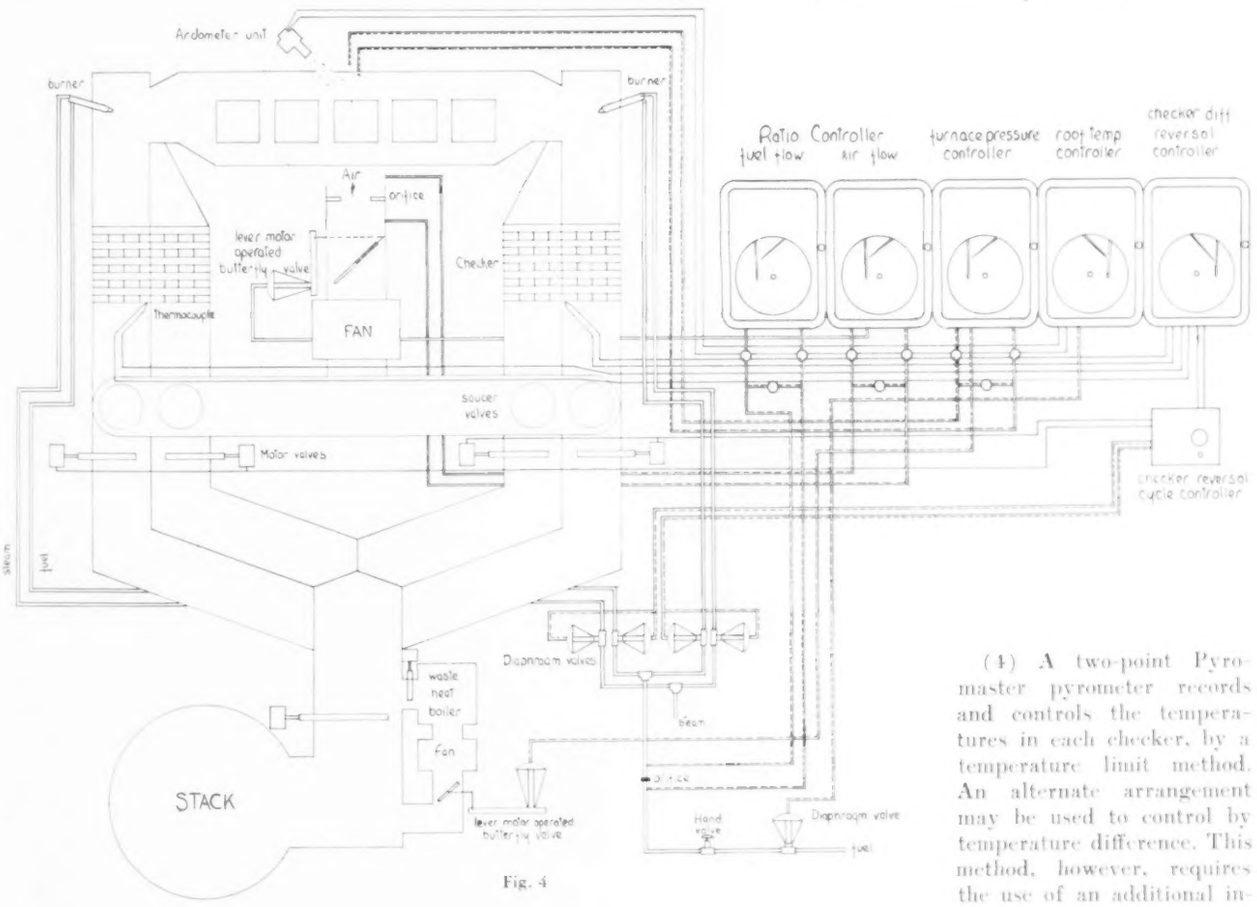


Fig. 4

(4) A two-point Pyromaster pyrometer records and controls the temperatures in each checker, by a temperature limit method. An alternate arrangement may be used to control by temperature difference. This method, however, requires the use of an additional instrument.

(5) Complete automatic reversal of the furnace is accomplished by a program cycle controller governed by the checker temperature controller.

Note that factors 3 and 4 are temperatures. In some important industrial furnace applications, combustion control is not complete without temperature control. This is particularly true of open-hearth furnaces where the

highest rate at which fuel may be fired depends upon the ability of the refractories to withstand high temperatures. Too high a fuel rate will cause sweating, fusing or stringing of the roof brick. In Fig. 5 is shown one method of controlling roof temperatures on an open-hearth furnace. The primary measuring element of the roof temperature control system is a total-radiation receiver sighted through the back wall on the inside of the roof. The output of this pyrometric receiver actuates a potentiometer movement in an air-operated temperature controller which commands a valve in the fuel line.

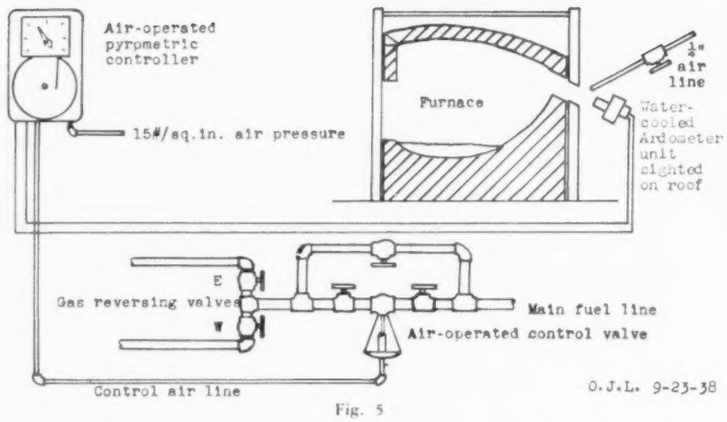


Fig. 5

In this article only certain applications are stressed, because the author believes that these applications have been under-controlled. The control systems described are adaptable to other types of heating equipment than the furnaces illustrated.

The Brooke System

By JAMES S. MERRITT, Jr.
Engineer, Brooke Engineering Co.

FOLLOWING is the description of an automatic combustion control system developed some two years ago with the idea of providing "metered" control to medium and large size stoker-fired boilers. Simplicity was considered to be essential.

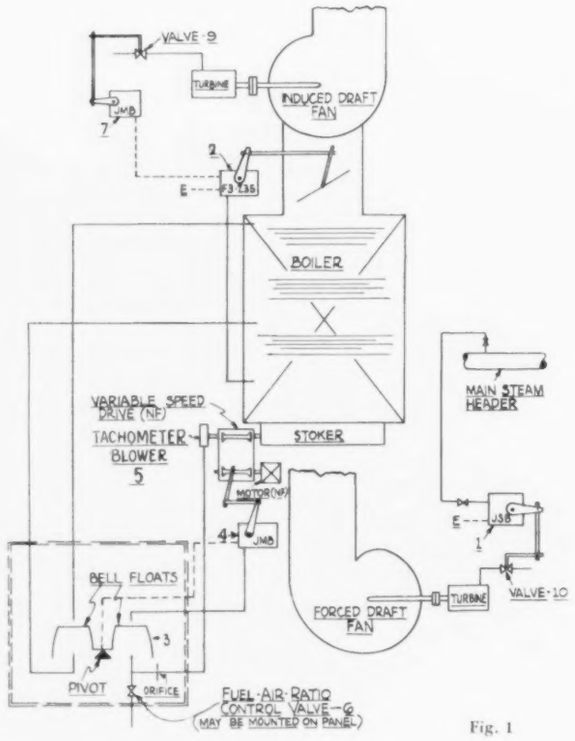


Fig. 1

Referring to Fig. 1, steam pressure is used to control forced-draft air either by varying the speed of forced-draft fan turbine or, if fan is constant-speed-motor-driven, by varying damper in fan outlet (damper not shown). Furnace draft is maintained constant by the operation of boiler outlet damper and also by controlling induced draft fan speed if the latter is turbine driven. Two mercoid switches applied to the shaft of the furnace draft regulator control the forward or reverse movement of motor unit 7, which does not move unless boiler outlet damper approaches either the shut or wide-open position. In this way induced draft fan speed is always maintained slightly in excess of that required.

Gas flow through the boiler is measured across the last two passes. The differential is applied to the left-hand side of bell floats 3. An increase in flow tends to rotate bells clockwise about pivot. A small tachometer blower is driven from the stoker mechanism and pressure from this blower is applied through orifice to right-hand side of bells 3. Compensated pressure from motor unit 4 is applied to top side of bell.

Upon a drop in steam pressure, more air passes through the stoker and boiler. Increased flow makes bell floats tilt clockwise, closing electric contact and causing motor unit 4 to increase stoker speed. Pressure from tachometer blower 5 is correspondingly increased until it is sufficient to balance increased differential on left-hand side of bell, breaking contact to motor 4 and stopping further movement.

Every time motor 4 runs, a small fan attached to one end of its shaft applies pressure or suction (depending upon direction of rotation) to upper right of bells 3, checking further movement and preventing overtravel. As bells 3 have relatively large area and will operate upon a change in pressure of 0.005" water column, this fan on motor 4 has a positive compensating action. This type of compensation is frictionless and does not interfere with rapid movement of motor 4 if there has been a sudden large change in load.

Inasmuch as the boiler air flow pressure differential measured on the left-hand bell varies as the square of the flow, and inasmuch as the pressure from blower 5

varies as the square of the stoker speed (which is zero when air flow is zero) the square factors of fuel-feed measurement and air-flow measurement cancel out. Thus no square-root cams or equivalent devices are required and coal feed is proportioned to air flow in accordance with movements of simple balanced bell floats.

To take care of changes in quality of fuel, the operator can increase or decrease stoker speed with relation to air flow by adjusting valve 6 which is normally mounted on the boiler control panel. Opening this valve decreases effective stoker speed, *i.e.*, causes stoker to run faster for a given air flow.

Fig. 2 shows the method of applying this system to several boilers. Item 18 is a small blower driven by a ¼ h.p. constant speed motor. If steam pressure drops, regulator 1 closes damper increasing master pressure. Master pressure varies between approximately ¼" and 1½" water pressure. Inasmuch as regulators 2 are equipped with electric motors the master pressure is a pilot pressure only and high-pressure air is not required.

Low-pressure air has the following characteristics: (a) Pressure changes are transmitted almost instantly, as in a draft gage; (b) There is no condensation, and so little dirt is carried through the pipes that strainers are unnecessary; (c) Piping work is easily made; (d) Since air flow is to be measured by differential pressure, a master pressure of like magnitude permits direct balance against air flow or tachometer pressure if such arrangement is desired; (e) Supply of low-pressure air can be obtained from a motor-driven blower set of extreme simplicity and dependability.

The rest of the system operates exactly as previously described. In addition, however, Fig. 2 shows remote control switches, one for each motor unit. In practice, these switches are each equipped with two bull's eye lights. These lights are normally lit and by blinking indicate to the operator:

(1) That electric current is on that particular motor unit.

(2) Whether the motor unit is in balance.

(3) If the unit is not in balance in which direction it is moving and approximately how fast it is moving.

(4) When the unit reaches the limit position.

The hand control switches enable the operator to hand set the regulator in any desired position or place it under automatic control.

Fig. 3 shows a view of a large stoker-fired boiler installation, made about two years ago, before the use of indicating lights on the panel was common practice. Regulator in top center operates the stoker control governor valve by means of sprocket and chain. A tachometer blower, driven from stoker shaft, is shown in circle at right.

Thus, all the essentials of full "metered" control are obtained in the most direct manner. All regulators are equipped with hand-auto-switches and pilot lights. Fuel-air ratio is easily adjusted from the boiler panel.

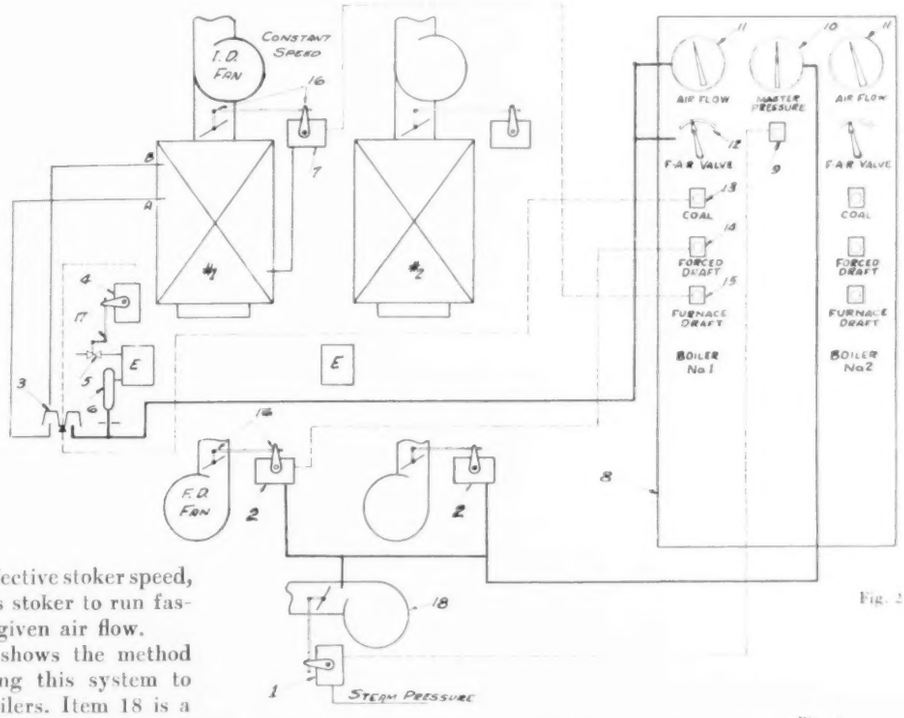
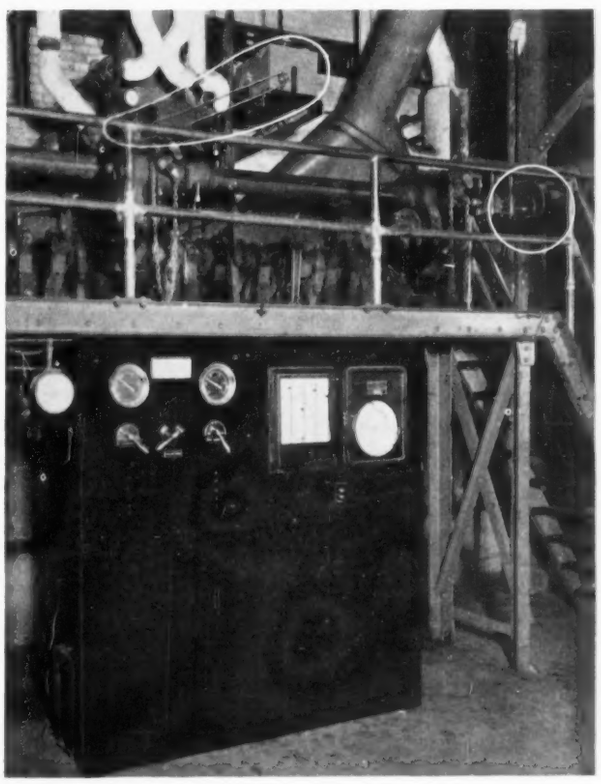


Fig. 2

Fig. 3



The Brown System

By H. M. SCHMITT
Engineer, The Brown Instrument Co.

BROWN Boiler Regulators are manufactured by the National Regulator Co. (also a division of the Minneapolis-Honeywell Regulator Co.) They were sold under the trade name of A-Jacks for more than twenty years.

The steam pressure regulator, Fig. 1, and the over-fire or draft regulator, Fig. 2, are designed for application on boilers under 1000 h.p. generating steam at pressures from 25 to 300 lbs. The pistons (effective area approx. 12 in.^{2}) are operated directly from boiler pressure, thus minimizing auxiliary equipment and piping and providing ample motive power. The exhaust steam from the cylinders passes between the double cylinder walls to serve as a steam jacket and minimize condensation.

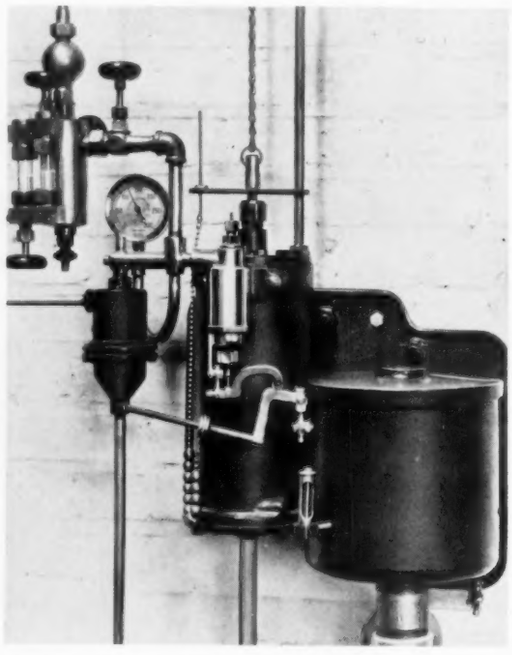


Fig. 1 (left). Brown steam pressure regulator. The curved rod is part of the adjustable compensator which controls the throttling range.

Fig. 2 (center). Brown over-fire or draft regulator. In this controller, the anti-hunting feature is a throttling screw between governor and cylinder.

Both the steam pressure regulator and the over-fire regulator are of the throttling type with adjustments to limit piston travel for a given change in steam pressure or draft. For example, the adjustable compensator on the steam pressure regulator may be set so the piston will travel its full distance on a pressure change of 25 lbs. or it may be set so that a pressure change of only 2 lbs. will cause the piston to move through its full travel of 10".

Brown Boiler Regulators may be applied to coal, oil or gas-fired boilers. Fig. 3 shows a steam pressure regulator (A) and an over-fire regulator (B) applied to a boiler equipped with a steam-driven stoker and a steam-driven forced-draft fan. When an increase in load occurs, the steam pressure regulator increases the opening of the uptake damper and speeds up the stoker by admitting more steam to the stoker engine. The over-fire regulator responds to the change in the uptake damper position and causes more air to enter the combustion chamber to meet the increased fuel requirement by opening the throttling valve in the steam line to the turbine driving the forced-draft fan. In the case of a constant-speed forced-draft fan, the over-fire regulator may be connected to a damper in the forced-draft duct as shown by the dotted lines.

In power plants having several boilers connected to the same header, a single steam pressure regulator can be used to operate the uptake dampers and fuel feed on all boilers while individual over-fire regulators control the air supply to the combustion chamber of each boiler.

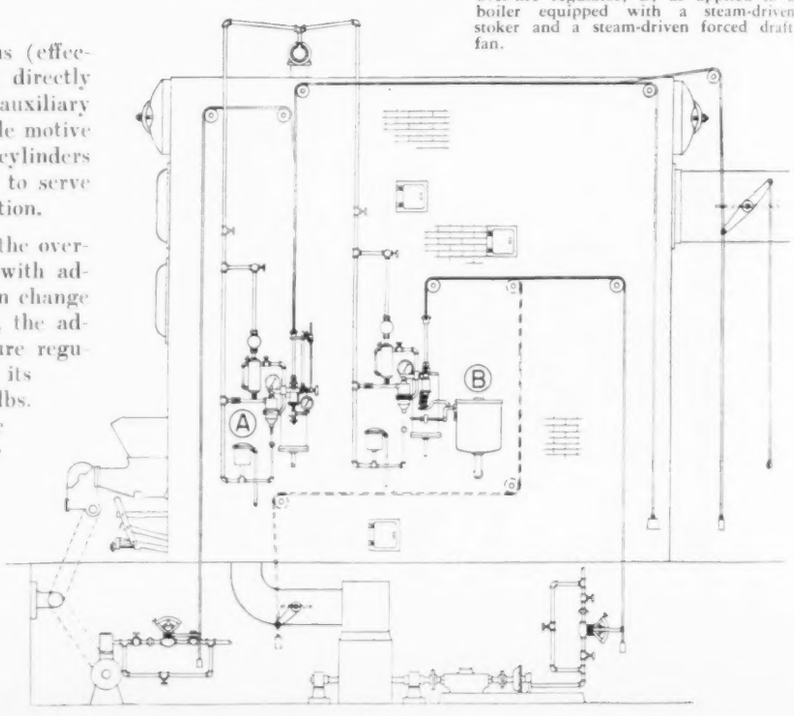


Fig. 3 (below). Schematic drawing of a steam pressure regulator, A, and an over-fire regulator, B, as applied to a boiler equipped with a steam-driven stoker and a steam-driven forced draft fan.

The Cash System

By J. J. KLINKER

Mgr., Combustion Control Div., A. W. Cash Co.

CASH combustion control equipment for any particular installation depends to a large extent upon the type and design of the major equipment. In some cases separate controllers may operate independently; in others the various units should bear some definite relation to one another.

Fig. 1 is a section of a furnace draft controller, applicable to both old and new boiler units and with every type of fuel burned. It may be included in complete control systems as shown in Figs. 3, 4 and 5.

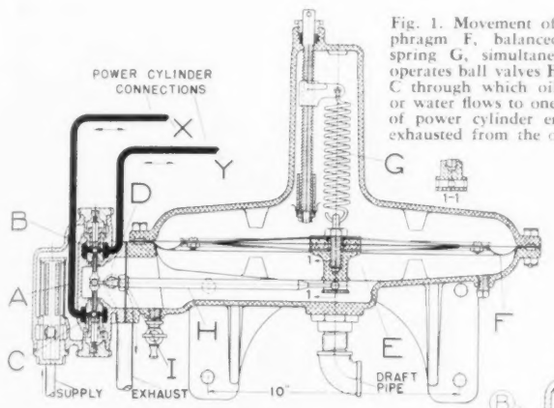
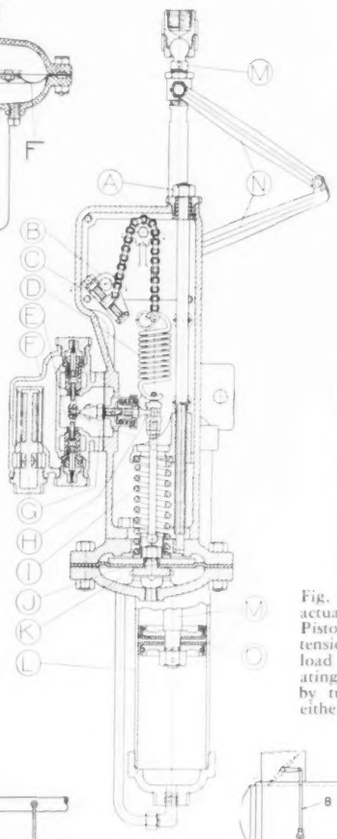


Fig. 1. Movement of diaphragm F, balanced by spring G, simultaneously operates ball valves B and C through which oil, air or water flows to one side of power cylinder end is exhausted from the other.

Holding the furnace draft at a low negative pressure is not enough for maintaining a constant fuel-air ratio. Means must be provided also for automatically controlling the rate of fuel feed and air supply in some fixed relation with the steam demand. A controller as shown in Fig. 2 may be used for adjusting the speed of the stoker driving unit or otherwise regulating the rate at which the fuel is fed into the furnace.

For simple systems and certain plant conditions, forced draft and fuel feed may both be regulated by the steam-pressure-actuated master controller. Of course, this system should also include the furnace draft regulator for maintaining constant negative furnace draft. See Fig. 3.

A more efficient system, Fig. 4, provides positive control of the air supply. The master controller regulates the rate of fuel feed according to the change in load as reflected in the boiler steam pressure. Air for combustion is regulated by an air flow controller, the diaphragm chambers of which are connected to the furnace and last pass of the boiler. This controller is, therefore, responsive to air flow but is coördinated with the action of the steam pressure controller to vary the air pressure to the stoker wind box so as to give a supply of air proportional to the rate of fuel feed. It also compensates for variations in fuel bed thickness or resistance. The furnace draft controller which operates the uptake damper is actuated by the furnace pressure and, being independent of the other two controllers, it maintains the desired furnace draft regardless of changes in boiler load, fuel feed, or air supply.



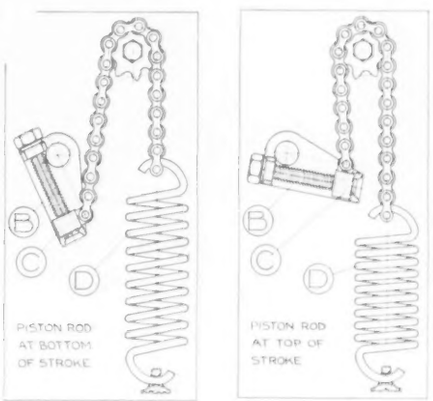
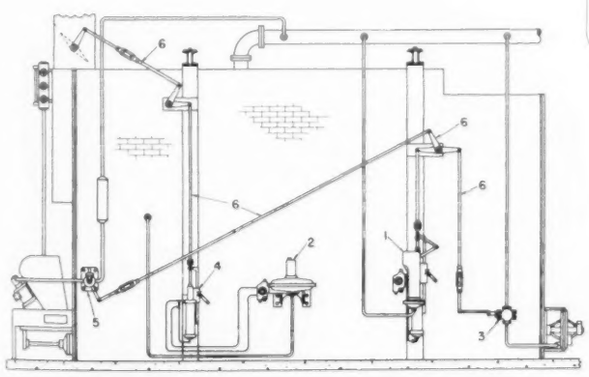
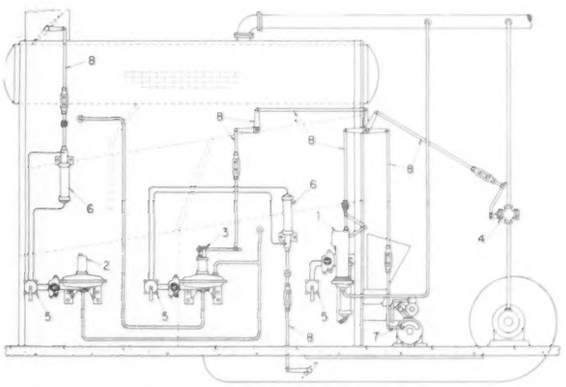


Fig. 2. Master controller. Movement of control diaphragm J actuates four-way valve F which energizes power piston O. Piston movement swings compensator lever B, changes tension of compensating spring D, altering effective spring load and bringing piston to rest at proper position. Operating range is adjusted by moving C along B, steam pressure by turning nut A. Sensitivity is not altered by making either adjustment.



1 - TYPE "100 WH" MASTER CONTROLLER
2 - TYPE "90" FURNACE DRAFT CONTROLLER
3 - TYPE "42" STEAM CONTROL VALVE
4 - 8440 HAND OPERATOR & POWER CYLINDER
5 - STOKER STEAM CONTROL VALVE
6 - RIGID TYPE OPERATING ACCESSORIES

Fig. 3. Application of Cash "standard" system.



1 - TYPE "100 W" MASTER CONTROLLER
2 - TYPE "90" FURNACE DRAFT CONTROLLER
3 - TYPE "95" AIR FLOW CONTROLLER
4 - TYPE "42" STEAM CONTROL VALVE
5 - 8430 HAND CONTROL VALVE
6 - 8435 POWER CYLINDER
7 - FUEL FEED CONTROL
8 - RIGID TYPE OPERATING ACCESSORIES

Fig. 4. Application of Cash "metered" system.

A somewhat similar control system applied to unit-fired pulverized coal installations is shown in Fig. 5. Here again, the master controller regulates the rate of fuel feed. Air for combustion is regulated by an air pressure controller, the diaphragm chamber of which is connected to the air duct or wind box. The controller is responsive to changes in air pressure at that point and is coördinated with the action of the steam pressure controller to vary the duct pressure so as to give a supply of air proportional to the rate of fuel feed. Here again, the furnace draft is maintained constant by a furnace draft controller independent of the other two controllers.

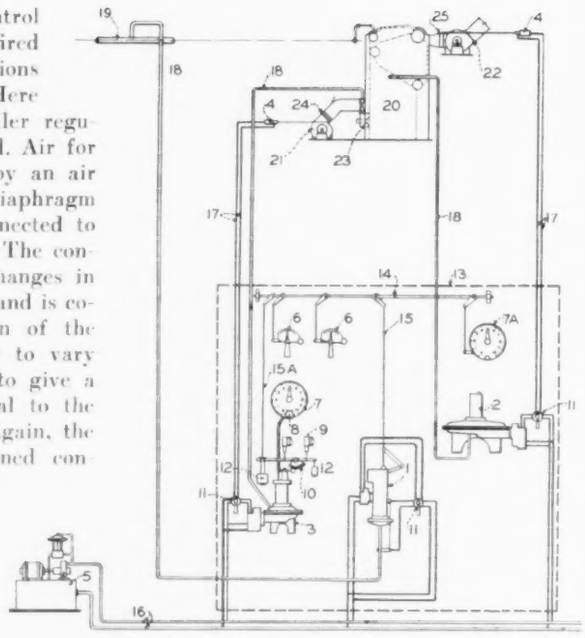


Fig. 5

The air flow controller shown in Fig. 4 and the air pressure controller shown in Fig. 5 are of the same general type as the furnace draft controller, which, when actuated by the master controller, readjusts the air flow or air pressure to correspond with changes in fuel feed. The power cylinders may be located near the equipment to be regulated.

By the addition of hand control valves, automatic control may be instantly interrupted and the unit under control placed in any desired position where it may be held indefinitely:

When the pointer of the hand control valve is at A (as marked on the valve body) the power cylinder is moved automatically and the operating fluid then flows through the hand control valve without change. When the valve lever is turned to mark O, the hand control valve cuts off the automatic control and directs the flow of the operating fluid to the power cylinder so that the attached unit (damper, throttle, etc.) will move toward the open position.

Moving the lever to C reverses the flow to the power cylinder so that the unit under control is moved toward the closed position. All movements of the power cylinder are arrested when the lever is at S. The hand control valve may be mounted directly on the controller or, if more convenient, at the front of the boiler or on the instrument panel and connected to the power cylinder and the pilot valve of the controller through copper tubing.

Another method of manual control may be obtained by substituting the hand operator and power cylinder for the standard cylinder. (This hand operator and power cylinder shou'd of course be located accessibly.) To interrupt automatic control and to manually adjustthe unit under control, the operator moves the lever to the left, and turns the hand crank until the piston and unit to which it is attached reach the desired position. The star wheel is then turned to hold the gear stationary.

The Cash standard automatic combustion control system may be applied to a plurality of boilers of any size and using various types of fuel burning equipment. It is most desirable that the master controller (the heart of the control system) be common to all units so that a load change will cause a response in the rate of combustion at each of the boilers to maintain the desired load distribution. The furnace draft, air flow and air pressure controllers, etc., are usually duplicated at each boiler.

The DFC System

By FRANK GAWAN

Mgr. Industrial Instruments Dept., Denver Fire Clay Co.

THOUGH primarily designed for controlling steam generators, DFC automatic combustion controls may be applied to other types of fuel-fired furnaces. When applied to a steam generator, they maintain the steam pressure constant by proportioning the fuel input to the steam demand; they proportion the combustion air input to the fuel input, and maintain the CO_2 or excess air constant at all loads on the boiler.

They are electrically-operated systems. They are "fully proportioning" controls and not "position" controls.

Four models are available: GND for application to gas-fired boilers operated under natural or induced draft and fired with atmospheric gas burners; GFD for boilers fired with gas under both forced and induced draft; OND for boilers fired with oil and operated under natural or induced draft; and OFD for boilers fired with oil and operated under both forced and induced draft. Any of them can be arranged to control either gas or oil when applied to boilers equipped with combination burners. The basic operating principle of all models being the same, this description will be limited to Model GFD.

It consists of a control cabinet containing the control units and a switch case; two motorized damper-operating mechanisms, one for operating the forced draft damper, the other for operating the induced draft damper; and a motorized fuel control valve.

The control cabinet is shown in Fig. 2 with front panel removed, also at A in Fig. 2. It is approximately 72" high. Three control units are mounted in the back of the cabinet with hinged doors in front of each unit. All electrical equipment for each unit is mounted on the back of its door and is accessible when the door is open. The top unit is the steam pressure control unit. The second unit is the forced draft control unit, and the third, the induced draft control unit. Immediately below the control units is the switch case which contains the line and selector switches, also thermal overload circuit breaker and alarm relay. When open, this door affords access to the terminal strips where all electrical connections are made. Pipe connections with suitable shut-off valves for connection to the steam header, burner manifold, forced draft wind box and furnace pressure connections, also openings for electrical conduit are provided at the back of the cabinet.

Each of the motorized damper-operating mechanisms (E and F in Fig. 2) consists of a reversible capacitor type electric motor driving a crank through a multi-stage worm gear speed reducer. Limit switches are provided.

The motorized fuel control valve is a balanced rotating stem lever valve (G in Fig. 2) operated by a reversible electric motor with built-in reduction gear and limit switches (D in Fig. 2).

A typical installation of Model GFD is shown in Fig. 2. A is the automatic combustion control cabinet; B is a boiler room instrument panel equipped with recording and integrating steam flow meter, CO_2 and stack temperature recorder; C is a draft gage panel containing a four-element pointer type indi-

cating draft gauge indicating gas pressure, forced draft wind box pressure, furnace draft and last boiler pass draft; D is the fuel valve operating motor controlling valve G; E is the forced-draft damper-operating mechanism connected to damper H, and F the induced-draft damper-operating mechanism connected to furnace outlet damper I. ½" conduits O carry three wires each from the control cabinet to the valve-operating motor, forced-draft and induced-draft damper mechanisms.

The control units in the control cabinet are provided with control beams pivoted at A, B and C (Fig. 1). The opposite ends of these beams are between electric contacts D & E, F & G, H & I. Under the steam pressure control beam and forced draft control beam are two pressure elements. Under the induced draft control beam there is one. Elements J and K operate the steam pressure control beam, elements L and M the forced draft control beam, and element N the induced draft control beam.

The steam pressure control unit maintains the steam pressure by operating the motorized fuel valve G (Fig. 1), proportioning the fuel input to the steam demand. The forced draft control unit maintains the fuel and air input ratio by operating the forced draft damper H. The induced draft control unit maintains the furnace pressure constant by operating the motorized induced draft damper I. When the boiler is operating at its normal load and with the steam pressure normal, the steam pressure control beam is balanced and both contacts D and E (Fig. 1) are open. Assume that steam demand increases, causing a drop in steam pressure. The pressure in element J which is connected to the steam header at J (Fig. 2) is relieved, allowing the beam to move downward and close contact E, thereby opening valve G and increasing fuel input.

Pressure element K (Fig. 1) is connected to the gas header at K (Fig. 2). When gas valve G opens, this element expands, thereby again balancing the beam between contacts D and E.

When the fuel input is increased as outlined above, element L (also connected to the gas header at K) expands, disturbing the balance of the forced-draft control beam, closing contact G, thereby opening damper H and increasing air input.

Pressure element M (Fig. 1) being connected to the forced-draft wind box at M (Fig. 2), the increased pressure in this element offsets the increased pressure in element L and again balances the beam between contacts F and G.

Element N of the induced-draft control unit is an oil-sealed manometer connected to the boiler furnace over the fire at N (Fig. 2). When the fuel and air input to the furnace is increased, it tends to create a positive pressure in the furnace which is transmitted to element N causing it to close contact H, thereby operating the mechanism F, opening induced draft damper I. When the correct negative furnace pressure is again reached, the beam will be rebalanced between contacts I and H. Thus the induced-draft control unit maintains a constant furnace pressure at all boiler loads.

In case of a decrease in steam demand, the operation of all units is reversed. "Hunting" is eliminated by electric stabilizers R.

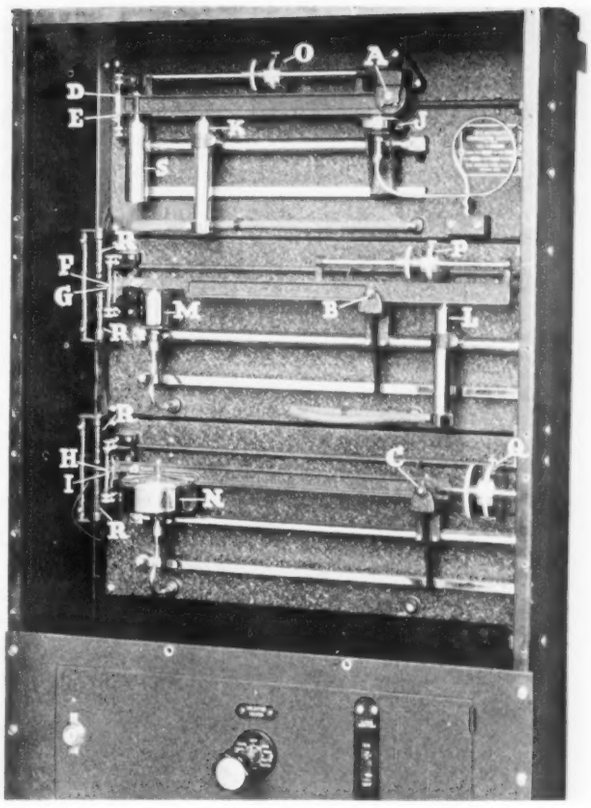


Fig. 1

A change in steam demand sufficient to cause change in steam pressure sets the control into operation, changing the fuel input in proportion to the new demand. The control, at the same time, adjusts the forced-draft wind box damper, changing the air input. The furnace pressure is held constant at all loads.

The control operates on the principle of balancing pressures

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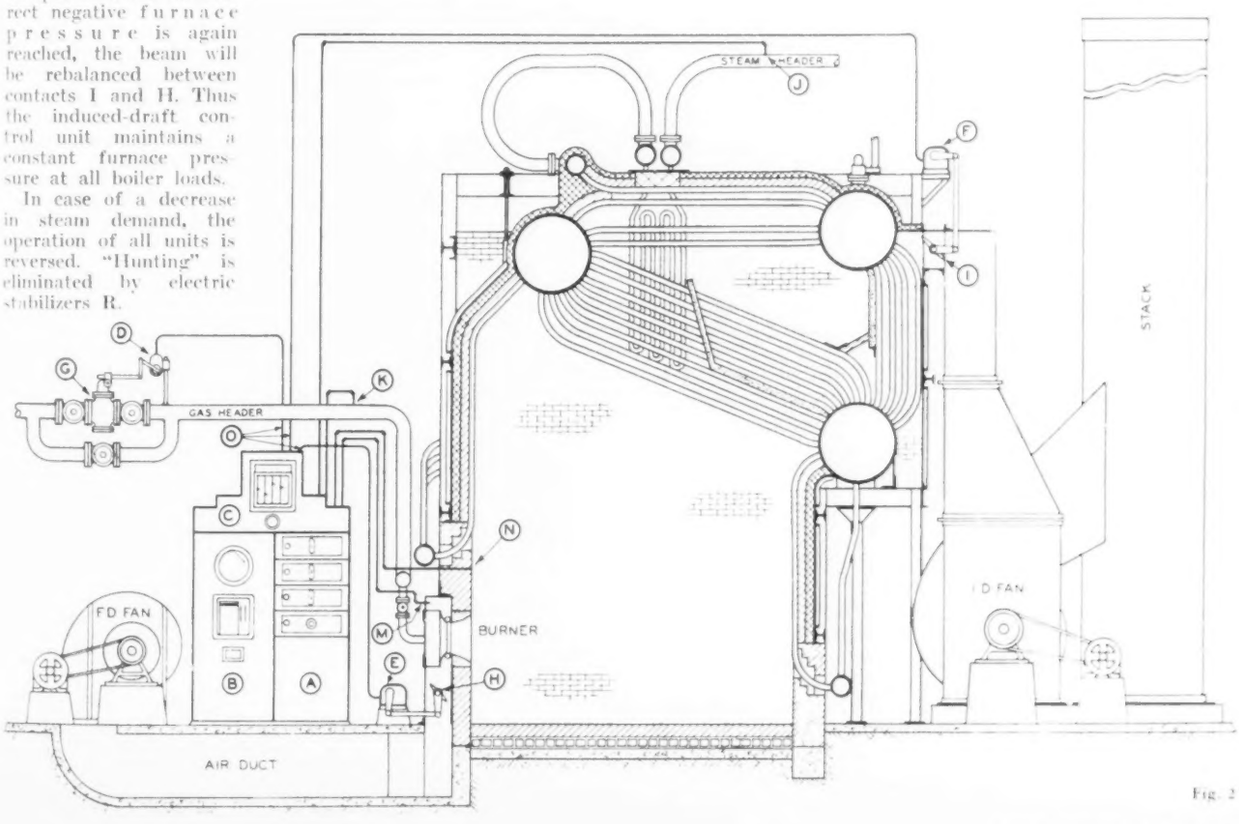


Fig. 2

The Dexter-Goebel System

By EDWARD F. GOEBEL
Chief Engineer, National Brass Co.

PRINCIPAL element of the Dexter-Goebel system of automatic combustion control is a master controller responding to steam header pressure. This master, known as the Dexter-Goebel Combustion Regulator, controls all subordinate units mechanically—by chains, shafts, etc., which operate dampers, valves, rheostats, etc. The requisite power is obtained from the steam pressure of the boilers under control. No supply of compressed air, electric energy or other form of auxiliary power being required, the system is thus of the "self-contained" type.

Fig. 1, drawn from photographs taken in a well-known automobile plant, brings out details of a typical installation.

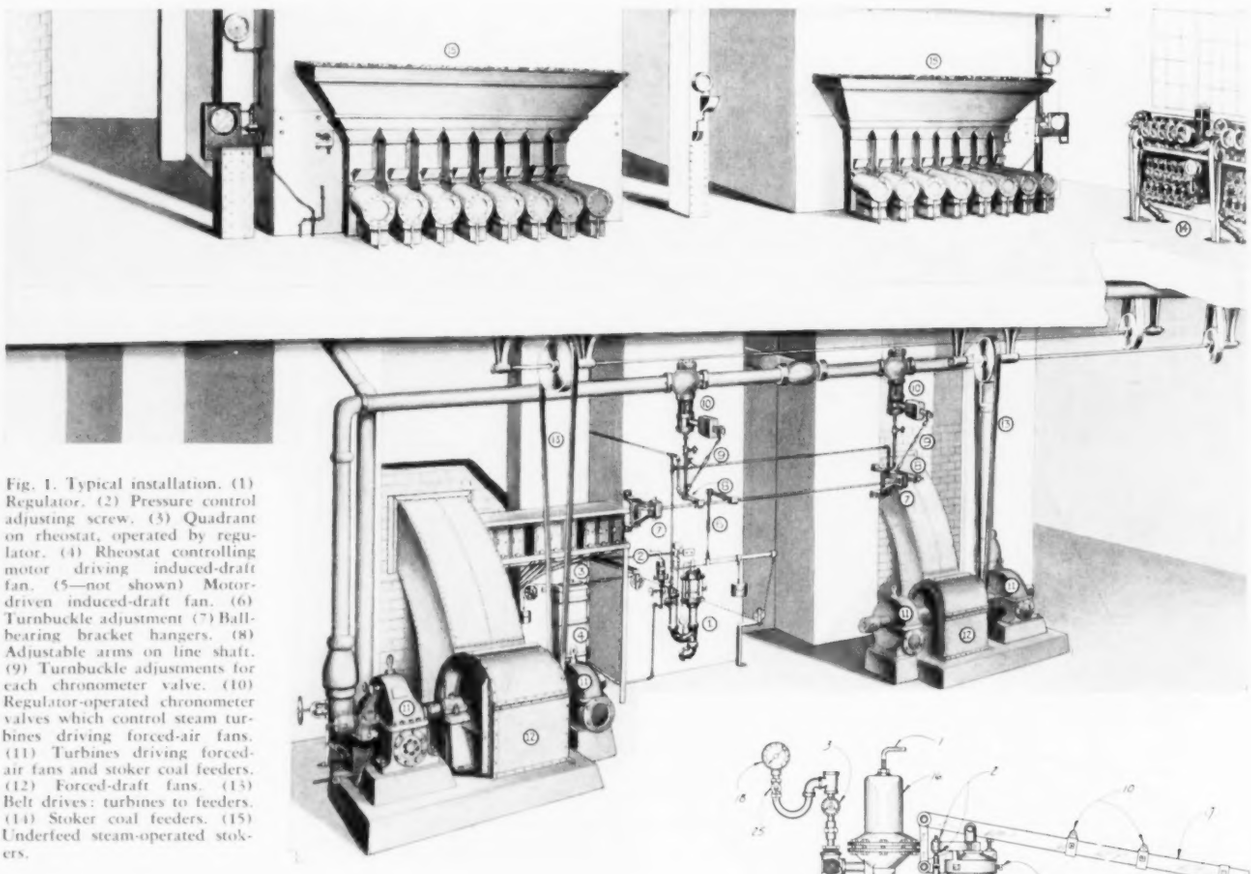


Fig. 1. Typical installation. (1) Regulator. (2) Pressure control adjusting screw. (3) Quadrant on rheostat, operated by regulator. (4) Rheostat controlling motor driving induced-draft fan. (5—not shown) Motor-driven induced-draft fan. (6) Turnbuckle adjustment (7) Ball-bearing bracket hangers. (8) Adjustable arms on line shaft. (9) Turnbuckle adjustments for each chronometer valve. (10) Regulator-operated chronometer valves which control steam turbines driving forced-air fans. (11) Turbines driving forced-air fans and stoker coal feeders. (12) Forced-draft fans. (13) Belt drives: turbines to feeders. (14) Stoker coal feeders. (15) Underfeed steam-operated stokers.

Fig. 2 is an outline illustration of the Dexter-Goebel Combustion Regulator and will demonstrate its operation. Its main feature is a constant-water-filled U-tube which makes possible the use of steam pressure for regulator operation without allowing the steam to come in contact with the power piston. This eliminates possibility of the piston freezing and the need for lubricators, packing glands, stuffing boxes, etc.

Header steam pressure is introduced to a balanced regulating valve, which opens and closes in ratio to the variances in steam pressure. This flow of steam applies against the water column, which actuates a piston. This piston, in turn, is connected to the fuel and air feeds through a system of levers and linkage. A bleed valve, also connected to the piston, releases the pressure which acts upon the water column, allowing the piston to return. The result is that a continuous process of balancing the steam demands with the fuel and air feeds takes place.

Synchronization of the fuel and air feed controls is made upon a lever which allows a travel of 3″ to 18″. Brief analysis will follow through the different phases of this operation which creates this continuous balance.

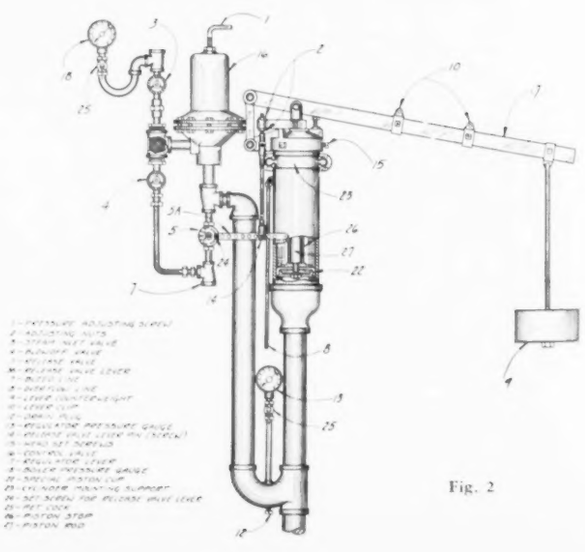


Fig. 2

The G-E System

By H. M. WEBBER

Application Engineer, Industrial Heating Dept., General Electric Co.

FOR heat-treating applications requiring protective atmospheres, G-E automatic combustion control equipment comprises furnace auxiliaries which are not "controllers" in the usual sense but take the form of gas mixing and processing units. The equipment may consist of only one unit—the G-E combustion-type furnace-atmosphere controller shown in Fig. 1. Available accessories are:

(1) A gas cooler; (3) Sulphur-removing towers;
(2) An absorption dryer; (4) CO_2 removing towers.

Another type of furnace-atmosphere controller sometimes used is the ammonia dissociator, Fig. 3.

A typical combustion-type furnace-atmosphere controller for partly burning hydrocarbon gases is illustrated in Figs. 1 and 2. Raw gas enters through flow meter B and air is drawn from the room through filter A and flow meter C. The mixer is an accurate sleeve valve consisting of a sleeve and a piston, each with two square

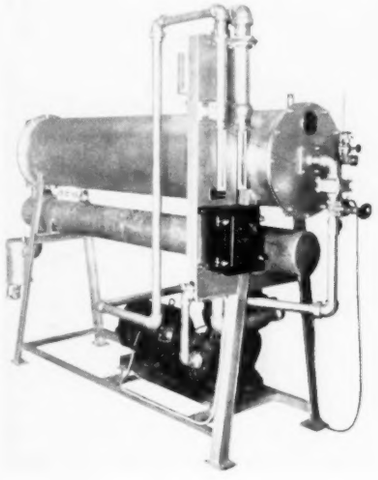


Fig. 1. Combustion-type furnace-atmosphere controller, rated at 2000 ft.³/hr. output.

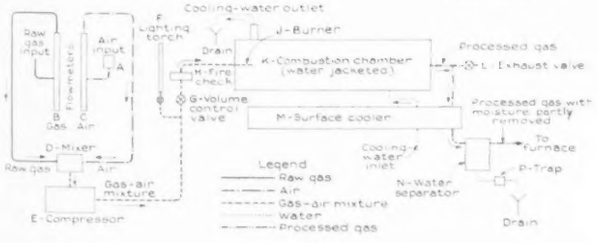


Fig. 2. Schematic diagram of combustion-type furnace-atmosphere controller.

orifices, one for gas and one for air. The piston can be rotated manually to adjust the gas-air ratio, and it moves vertically for changes in mixture volume. Vertical movement during operation takes place automatically to meet demand. The gas enters the mixer through a governor which regulates the pressure at which it is introduced, and this pressure is always the same as the prevailing air pressure. Automatic equalization of these pressures, automatic piston adjustment, and close-tolerance machining of the square ports assure accurate volumetric and ratio control.* From the mixer the gas and air go through compressor E equipped with an automatic pressure regulator which maintains constant outlet pressure. From here the mixture travels successively to a lighting torch F, volume-control valve G, fire check H, and burner J.

Fig. 3 shows a typical ammonia dissociator rated 1000 ft.³/hr. Fig. 4 shows the piping arrangement for the dissociator with its accessories. Ammonia passes from a cylinder through a heat exchanger and an expansion valve into the dissociating element, which consists of a coil of alloy tubing filled with catalyst. Upon leaving the dissociator, the gas goes through the heat exchanger, a flow meter, a pressure reducing valve, then to the furnace. The dissociator is electrically heated, with ribbon resistors mounted on the side walls. An auxiliary panel is

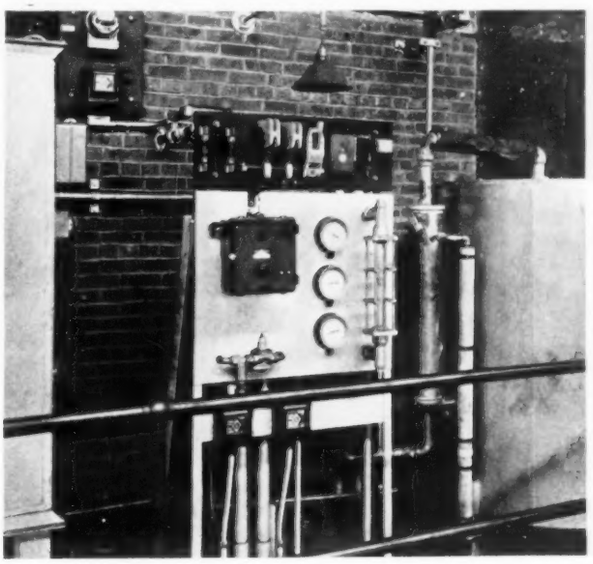


Fig. 3. Ammonia dissociator rated at 1000 ft.³/hr., 20 kw.

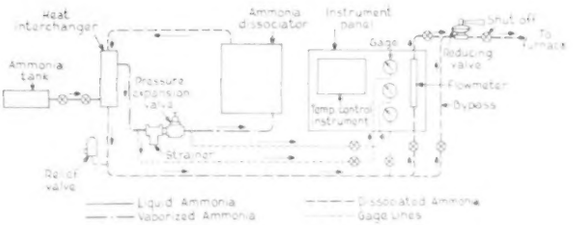


Fig. 4. Schematic diagram of ammonia dissociator.

provided to mount the flow meter, pressure gages, temperature control instrument, etc. The temperature is automatically controlled, of course, with a pyrometric system.

For some types of furnaces, it is necessary to supply the gas at low pressure—say 2″ to 6″ of water. Generally the gas is delivered from the furnace atmosphere controller or accessories at higher pressures than this and there is installed in the line to the furnace a pressure regulator to reduce and control the pressure.

*This is a development of The Selas Company, Philadelphia, Pa.

The Hagan System

By T. A. PEEBLES

Vice-President in Charges of Engineering, The Hagan Corp.

IN the Hagan System of automatic combustion control, compressed air is used both for loading purposes and as an operative medium to actuate the individual controls. Since steam pressure is a measure of the relation between heat input and demand, the control starts with a master responsive to steam header pressure and generates a loading pressure of air that varies with the steam pressure.

The manner in which the loading pressure is generated and switched at the control panel is illustrated in Fig. 1. The header pressure acting on the outside of metal bellows 1 is opposed by the tension of spring 3. The relation between these two forces determines the position of balance beam 2, and consequently the position of relay valve 8. This valve is movable between a seat at the bottom where air at constant pressure is admitted and an exhaust at the top. If the steam pressure is high, the valve is in its upper position, providing for a free admission of the air supply while the exhaust port is closed. The pressure in the valve chamber, therefore, reaches that of the constant pressure supply. If the steam pressure is low, the valve moves downward, closing the inlet port and opening the exhaust to reduce the pressure surrounding the valve to that of the atmosphere. For intermediate steam pressures, the valve assumes intermediate positions, and consequently the pressure surrounding the valve may have any value from atmospheric to the pressure of the air supply. In practice, air is supplied at 60 lbs. and the control is adjusted to utilize the variations between 50 and 10 lbs. This variable pressure furnishes the impulse that actuates the control system.

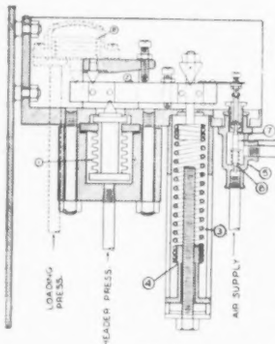


Fig. 1

The impulse passes through a transfer valve to a relay mounted on the panel. See right-hand portion of Fig. 1. In normal operation, this relay simply reproduces the loading pressure received from the master. The received pressure acts on diaphragm 11 and is balanced by the pressure on a similar diaphragm 12. If these two pressure are not in balance, pilot valve 13 moves either to admit constant pressure air or to exhaust to the atmosphere.

The operator may adjust the relay to send out a higher or lower pressure than it receives by adjusting handwheel 16. This permits manual adjustment of the relation between loading pressure received from the master and that sent out to the individual control devices.

If manual operation from the panel is desired, the transfer valve is thrown to the manual position. This cuts off the loading pressure from the master and reduces the pressure on diaphragm 11 to atmospheric. The operator may then send out any desired loading pressure by adjustment of handwheel 16.

Leakage in the loading lines from the panel to the individual regulators does not affect the accuracy of control, because the construction of the relay requires that the established relation between the pressures acting on diaphragms 11 and 12 shall be maintained. For instance, if the pressure acting on diaphragm 12 falls due to line leakage, pilot valve 13 admits high-pressure air to the system until the correct pressure relationship has been reëstablished.

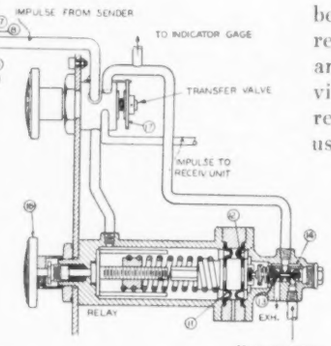
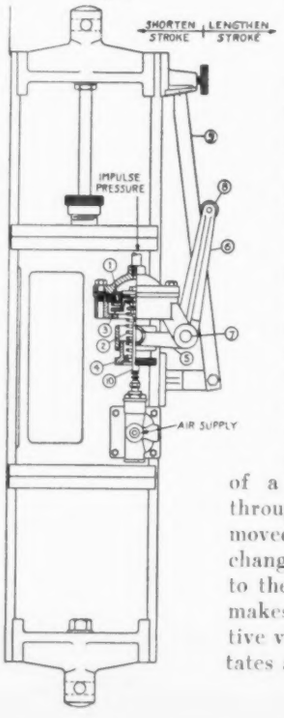


Fig. 2

The loading pressure from the panel is utilized to actuate any one of a number of regulating devices, depending on the requirements of a particular installation. For the operation of valves, dampers, rheostats, etc., the receiving regulator illustrated in Fig. 2 is used. The loading pressure acts on diaphragm 1, and is balanced by compression in spring 2, which is adjusted by means of spring nut 4. The regulator is in equilibrium only when the loading pressure and the force due to the spring are in balance. If the loading pressure increases, pilot valve 10 is moved downward, admitting air to the bottom of the power cylinder, and producing an upward movement of the crosshead. This carries compensator 9 upward, and forces roller 8 and lever 6 to move to the right. This lever is pivoted at 7 and at its other end carries spring nut 4. Upward movement of the regulator, therefore, acts to increase the compression in spring 2 until a balance is established between this compression and the pressure of air on diaphragm 1, At this time, the pilot valve comes back to its neutral position, and movement of the regulator is stopped.

When it is desired to provide means for adjusting the ratio of proportionality between a loading pressure received from the master, and that sent out to an individual regulator, the ratio relay shown in Fig. 3 is used. The left-hand barrel of this relay receives the master loading pressure and exerts a force on the balance beam dependent upon the value of this loading pressure. Movement of the beam actuates a pilot valve which admits air to or exhausts air from the right-hand barrel. The relation between incoming and outgoing pressures is determined by the position of the fulcrum, which can be adjusted by the handwheel on the front of the panel. An indicator mounted above the relay handwheel shows the condition of the adjustment.



When steam-driven auxiliaries are to be controlled, it is difficult to determine the correct valve size for good regulation. The exact pressure or suction against which a fan may be required to work cannot be predicted and a margin of power must be provided for unusual conditions. To provide a valve having a wide range of field adjustment, the construction illustrated in Fig. 4 is employed. The loading pressure acts on the outside of a metal bellows, which actuates the steam valve through an adjustable fulcrum. When this fulcrum is moved to the right, the valve movement for a given change of loading pressure is increased. When it is moved to the left, the movement is decreased. This adjustment makes it possible to secure a four-to-one change in effective valve area while the valve is in operation, and facilitates adjustment to suit local conditions.

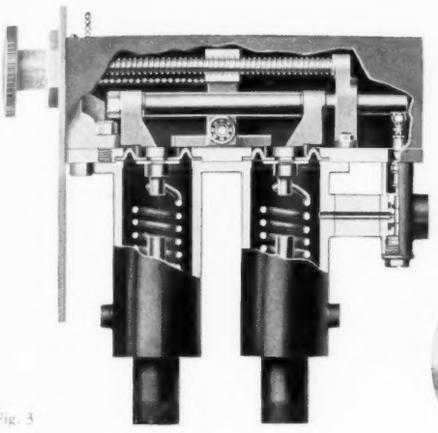


Fig. 3

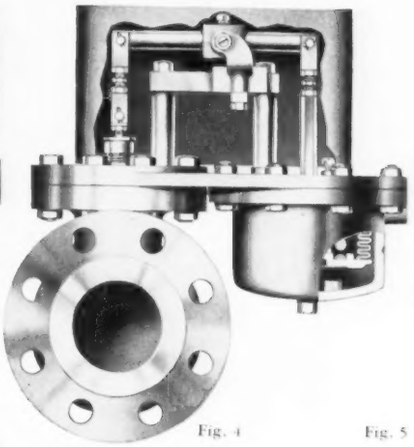


Fig. 4

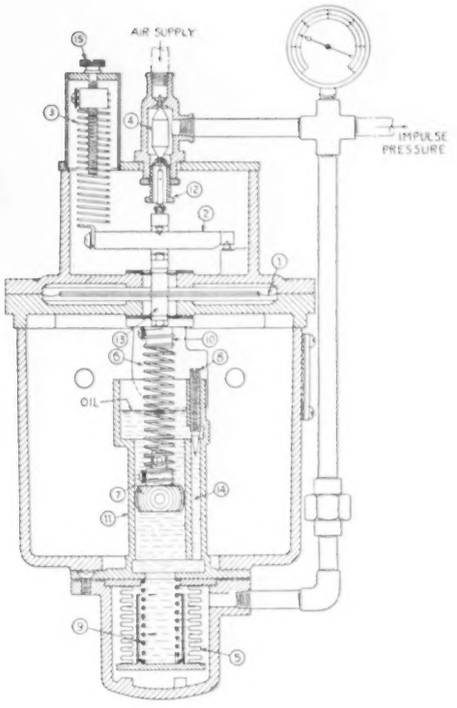


Fig. 5

For control of draft or differential, a diaphragm type of regulator is used. See Fig. 5. A departure from the desired value of the draft or differential to be regulated causes diaphragm 1 to move and adjust the position of relay valve 4. This valve (similar to that used in the master) generates a variable air loading pressure for control purposes.

For instance, a downward movement of diaphragm 1 causes relay valve 4 to increase the loading pressure, which is relayed to a receiving regulator, control valve, or other pressure-responsive mechanism used for control purposes. This increased loading pressure acts on the outside of metal bellows 5, whose movement is opposed by spring 9. The movement of this bellows will, therefore, be proportional to the increase of loading pressure. Upward movement forces oil upward in cylinder 11 and acts against piston 7. This alters the tension in spring 6 and temporarily alters the balance of forces between diaphragm 1 and spring 3. This loading maintains the diaphragm at equilibrium for a period of time dependent upon the adjustment of bypass valve 8. The time adjustment is made to correspond with the interval between a change in impulse pressure and the restoration of the regulated draft or differential pressure on diaphragm 1 resulting from movement of the valve or damper being controlled. Bypass valve 8 is set with a smaller opening for greater time intervals.

Seldom are two boiler installations identical in all respects concerning equipment to be controlled. The standard control units are arranged to suit. One arrangement is illustrated in Fig. 6. It shows a pulverized fuel-fired boiler with turbine-driven forced- and induced-draft fans. The loading pressure from master sender 1 is transmitted to air flow relay 2 and to fuel control relay 3. Relay 2 establishes a measured rate of air supply by loading regulator 8 which in turn controls the speed of the forced-draft fan by means of bellows-operated steam valve 5. Fuel relay 3 sends a loading pressure to receiving regulator 4, which adjusts the rate of primary air supply to the pulverizer. This relay also controls fuel feed regulator 13. Since the rates of fuel and air supply to the burners are maintained as definite functions of the master loading, these functions may be calibrated to secure accurate control of the fuel-air ratio throughout the entire operating range. The ratio type air flow relay provides the means for making proportional corrections of the fuel-air relationship to compensate for changes in quality of fuel or number of burners in service. A suitable indicator at the panel shows the extent and direction of any manual adjustments that may be made.

Draft regulator 11 controls the speed of the induced draft fan by means of bellows-operated steam regulating valve 9 to maintain a constant draft in the combustion chamber.

Control stations 6 and 10 provide manual control of forced and induced draft fan speed from control panel 12. Suitable indicating gages on this panel show the relationship of the various control elements and the extent of any manual adjustments.

If motor-driven fans were used instead of turbines, the details of the control equipment would be different, but the principle of regulation would remain the same.

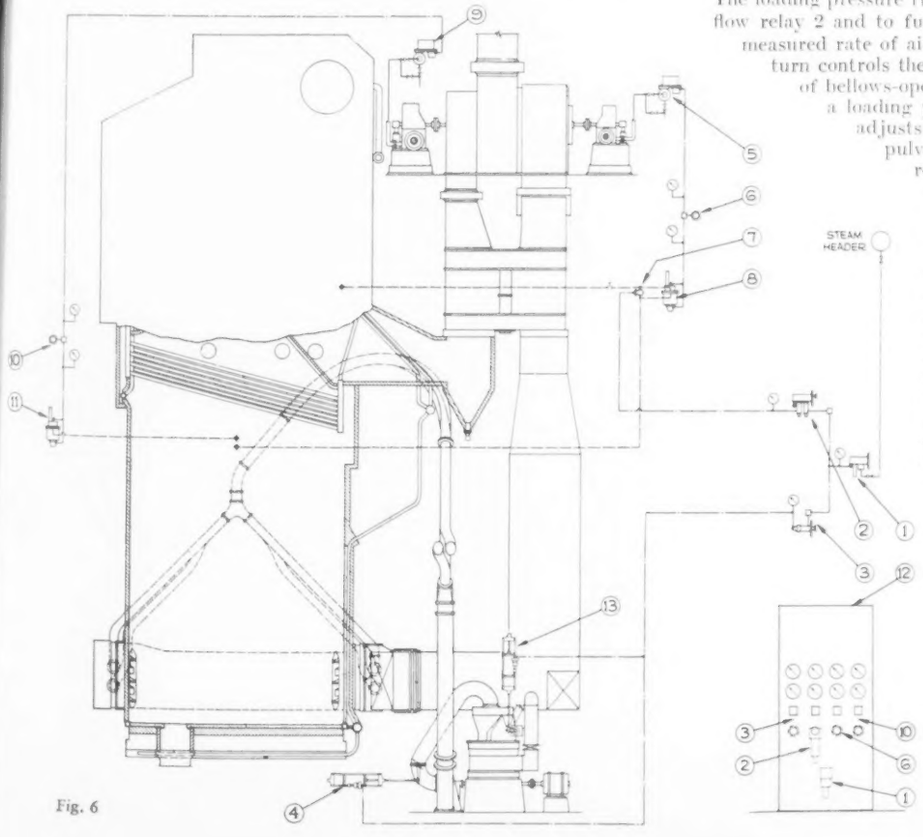


Fig. 6

The Hays System

By W. H. PUGSLEY

Manager of Engineering, The Hays Corp.

IN the Hays centralized system of automatic combustion control, all control and metering units are mounted on a panel which may be located at any point in the boiler room. See Fig. 1. Electrical transmission eliminates time lag. Manual operation is provided for each of the control units, by means of which special combustion conditions may be met or anticipated.

Master Controller (Fig. 2). Steam header pressure is piped to a master controller, where it acts upon a spring-loaded metallic bellows. The movement of the bellows is communicated to a beam with pivot or knife-edge bearings, the beam acting against a spring which provides an adjustable compression. The beam movement due to steam pressure change moves the magnet bar, making contact in one of the mercury switches to start the electric operator.

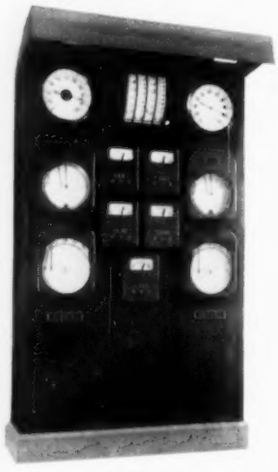


Fig. 1. Typical centralized control panel. This one has five control units (the rectangular-case instruments in center) as follows: one master controller and—for each of two boilers—an air flow control and a fuel feed control. All five are coordinated as explained in description of electric operator. All necessary indicating, recording and integrating instruments and meters are supplied by Hays and associated companies.

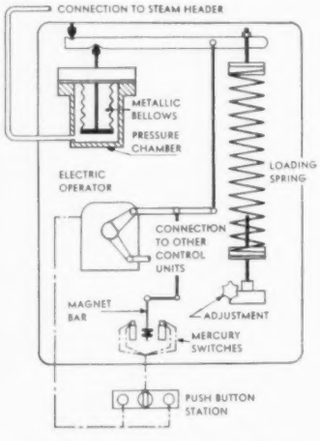


Fig. 2. Schematic diagram of the "Type HPME" master controller for high-pressure applications: its loading spring is at the end of the balance beam and its steam pressure chamber and metallic bellows are designed and constructed for high-pressure work.

In "Type LPME" for relatively low steam pressures, the loading spring and metallic bellows are coaxial: force and counterforce being co-linear, there is one knife-edge less and the balance beam is a simple lever.

The electric operator is connected by rigid connections to the air-flow control and the fuel feed control, causing these to change the rate of air flow and fuel feed to hold the steam at the desired pressure.

The shaft of the electric operator is extended to the inside of the case and is also linked to the magnet bar, causing a movement of the bar in the direction opposite from that caused by the change in steam pressure. This action breaks the contact in the mercury switch, stopping the electric operator. No further change takes place in the master control until the header pressure again varies. This scheme of interconnection is shown in Fig. 3.

Provision is made for adjusting the spring force to establish the pressure at which the master will operate. The linkage from the beam to the magnet bar can also be adjusted to control the sensitivity of response from increments of a few ounces to any lesser degree which conditions may demand. The linkage can also be adjusted to determine the pressure gradient of the unit. A small knurled knob at the side of the electric operator adjusts the speed of the response. Pressure setting, pressure gradient, sensitivity of response and speed of response can all be adjusted to meet the specific requirements of any type of fuel-burning equipment and any characteristics of load and combustion conditions.

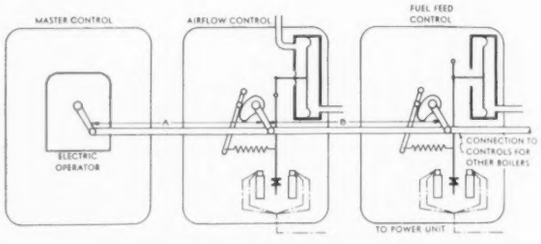


Fig. 3. Schematic diagram showing "rigid-connection" method whereby the movement of the electric operator in the master controller causes other control units on the panel-board to make appropriate responses in order to hold the desired steam pressure.

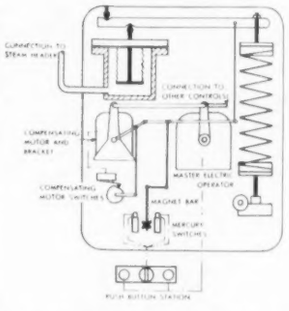


Fig. 4. "Type PCOME" Pressure compensator. To the standard master control (such as illustrated in Fig. 2) is added a small shaded-pole reversing motor, speed reducer and speed adjuster, all oil-immersed in a die-cast case and mounted in a movable bracket which is operated by the master motor. To the inside of the case is added a pair of switches operated through linkage by either the master motor or the compensating motor. The anti-hunting action is as follows: During the movement of the internal linkage of the master control due to load changes, contact is made in one of the compensating motor switches. This energizes the compensating motor and it in turn superimposes an adjustment in addition to that made by the master motor due to load changes, cutting out when the trend reverses, thereby asymptotically returning the steam pressure to the value for which the master has been set.

In high-pressure systems where extremely close pressure regulation is essential, a pressure compensator is incorporated in the master control to compensate for the pressure gradient of the unit and return the steam pressure to the required value regardless of wide changes in load. This eliminates any tendency toward hunting, yet retains all the advantages of close pressure regulation. Fig. 4 shows the essential details of this compensator.

Three toggle switches for manual operation of all the boilers being controlled are provided.

Air Flow Control (Fig. 5). The movement of the rigid connections from the master control adjusts a calibrated cam in the air flow control for the rate of air flow necessary to restore the steam pressure to normal. The calibrated cam is a true square root cam, removing this factor from the air flow formula.

The air flow control consists of a slack leather diaphragm unit in a differential housing, a set of mercury

switches, the calibrated cam, a set of three toggle switches for manual operation of the air volume control damper, an indicating scale and two indicators—one to show master adjustment and the other to show the amount of load adjustment made manually while on automatic control.

The rate of air flow is measured by the differential between two points in the gas passages in the boiler. A variation from the required rate moves the slack diaphragm, which in turn makes a contact in one of the mercury switches, starting the power unit (electric or hydraulic) to change the draft by changing the position of the damper. When the air flow has reached the desired rate and there is no variation in steam pressure, no further change takes place until the steam pressure varies or the rate of air flow varies from the rate desired for that particular load on the boiler. Variations in the differential due to varying stack draft and damper characteristics are compensated for by this control.

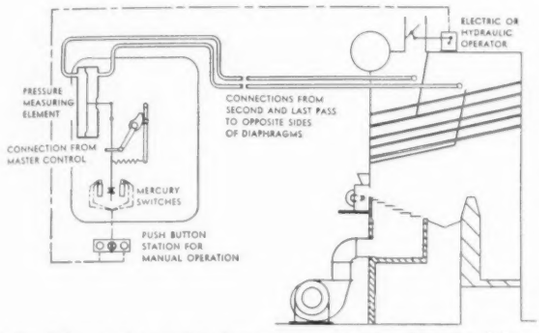

ELECTRIC OR HYDRAULIC OPERATOR
PRESSURE MEASURING ELEMENT
CONNECTIONS FROM SECOND AND LAST PASS TO OPPOSITE SIDES OF DIAPHRAGMS
CONNECTION FROM MASTER CONTROL
MERCURY SWITCHES
PUSH BUTTON STATION FOR MANUAL OPERATION

Fig. 5. Scheme of operation for air flow control, where the differential pressure across a boiler section is a measure of air flow.

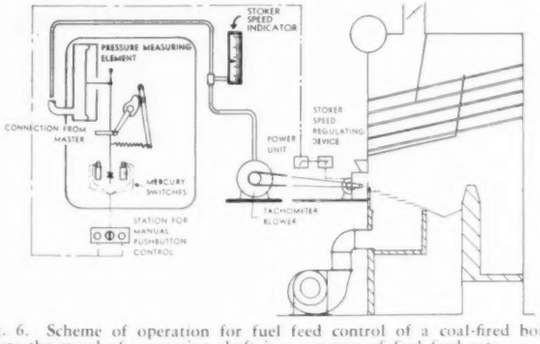


Fig. 6. Scheme of operation for fuel feed control of a coal-fired boiler where the speed of a rotating shaft is a measure of fuel feed rate.

Fuel Feed Control (Fig. 6). Simultaneously with the setting of the cam in the air flow control by the master, the calibrated cam in the fuel feed control is set by the same movement for the required rate of fuel feed.

The fuel feed control responds to the suction of a tachometer blower driven by a stoker or pulverized feeder table. This suction is a measure of the rate of fuel feed. As this suction varies, the slack leather diaphragm causes contact to be made in one of a set of two mercury switches to operate one of the several types of mechanisms which may be used to control the speed of the stoker or pulverizer feeder table. These include (1) a motor-operated valve in the steam line to the stoker engine or turbine, (2) a motor-operated rheostat which controls the speed of the motor driving a stoker or pulverizer feeder table, and (3) an electric or hydraulic power unit used to shift the lever of a variable speed transmission on a stoker or pulverizer feeder table.

When the speed is secured for which the control has been automatically adjusted by the master, no further change takes place. Variations in speed due to changes in load on the fuel feed drive or in the steam pressure at the engine or turbine, valve, rheostat, etc., are compensated for.

Fuel Feed Control for Oil- or Gas-fired Boilers is similar in that a flow control is used, but the instrument is of the (relatively) high differential type, designed for metering oils and gases. See Fig. 7.

Furnace Draft Control. To keep the combustion chamber draft constant a furnace draft control is employed in the Hays system when forced draft is used. It operates independently of the air flow and fuel feed controls.

Connection is made to the slack leather diaphragm housing by means of iron pipe or copper tubing. Variations in suction or draft move the diaphragm, causing one of the magnets to make contact in one of the mercury switches which starts the power unit (either electric or hydraulic) to move a damper or valve, or create a response to bring the suction or draft back to the value for which the control has been adjusted. This done, the contact is broken and no further change takes place until the draft again varies.

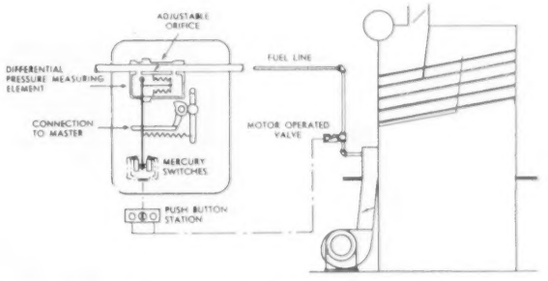


Fig. 7. Scheme of operation for fuel feed control of an oil- or gas-fired boiler, using "Type AHDE" automatic flow-rate controller.

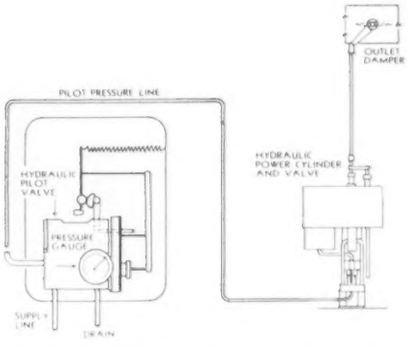


Fig. 8. Application of "Type AHYR" hydraulic remote pilot pressure control and Hays Hydraulic Power Unit.

To meet or anticipate unusual combustion conditions the control may be operated manually through toggle switches.

Other Units. This concise presentation has been limited to the Hays centralized system, featuring electrical transmission and application to ordinary steam-generating equipment. However, there are numerous other Hays instruments and devices for the automatic control of combustion in different types of industrial furnaces. Other types of Hays systems are in use which combine units not described above, among them remote-pilot hydraulic (Fig. 8) and remote-control electric operators.

The Metermax System

By EDWARD S. BRISTOL

In charge of Automatic & Combustion Control Div., Engineering Dept., Leeds & Northrup Co.

METERMAX Combustion Control is a pneumatic-electric system which utilizes the most useful characteristics of each class of system: air-loading, and electrical transmission. An additional feature is unit construction: all controllers and switches are grouped on a panel and shipped to the user as a completely assembled and wired unit.

To provide direct balance action for each controlled variable, Metermax utilizes null-type controllers which detect any unbalance between demand and supply (or equivalent) for their particular function, and, with a minimum actuating force, initiate control response. Combined with this balance principle is a metering action whereby each controller is subjected to a force representing the corresponding controlled variable. In the event any variable fluctuates, control response persists until it actually is returned to standard value.

Another Metermax principle is to maintain specified conditions as nearly as possible at the source. To this end, rates of supply of fuel and air are metered and controlled in order to maintain proper combustion conditions.

To apply these principles efficiently, an air-loading system transmits the master controller action to the various individual controllers, and electrical relays and drive units effect control response at dampers, valves, etc. Two types of automatic control are available:

(1) Master, in which all combustion factors at each boiler are continuously proportioned to steam demand;

(2) Individual base load, in which the various factors at a boiler are continuously held at constant values as determined by an individual manual loading adjustment.

There is also a complete electrical system of remote push-button controls.

Fig. 1 is a schematic layout of a typical control installation. The heart of the system is master controller A, which maintains a balance between heat demand and an air-loading pressure, thus determining the combustion rate maintained by the individual fuel and air controllers. Header steam pressure, used to indicate change of steam demands, acts through a Bourdon tube to reduce the force exerted by a loading spring on one end of a centrally-pivoted balance arm. At the other end of the arm is a combined throttle-bleed valve which adjusts air-loading pressure and, through the action of an unbalanced cup element, exerts a force on the balance arm dependent upon the loading pressure value. The overall action of the master controller is to balance air-loading pressure against drop in steam pressure. Because there is a square relation between header pressure drop and total steam flow, loading pressure is proportioned to the square of steam demand. Air leaving the supply unit is held by a reducing valve at a constant pressure of approximately 14″ of water. The master controller reduces this pressure to a value ranging from 0.4″ to 10″ of water in the loading lines, with a definite air pressure value for each steam pressure within the working range. A compensating attachment, employed at the master controller when constant header pressure is desired, functions to apply at a retarded rate a force change supplementing the original Bourdon tube action.

The fuel-feed controller maintains a balance between master air-loading pressure, acting on a diaphragm, and a force representing metered rate-of-fuel supply. In Fig. 1 is shown a controller suitable for use with a unit coal pulverizer having an instantaneous output closely pro-

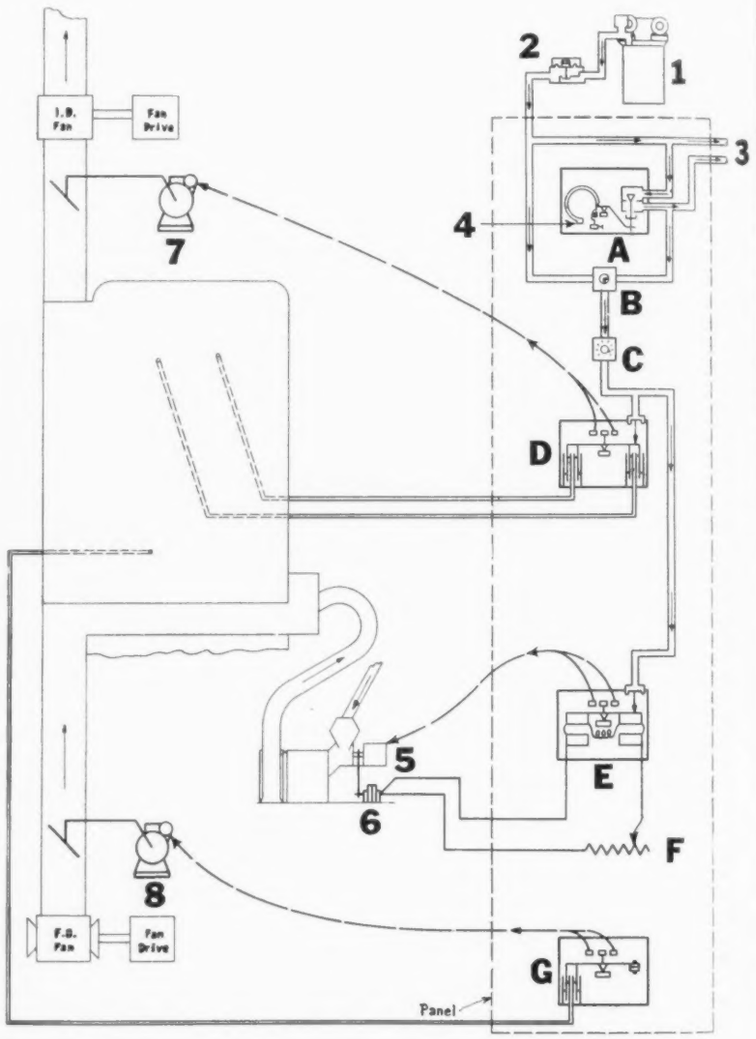


Fig. 1. Schematic diagram of Metermax Combustion Control for pulverized-coal-fired boiler.

A—Master Controller adjusts air loading pressure in response to steam demand.
B—Transfer Valve provides master or base-load control.
C—Load Adjustment Valve. Its setting determines boiler loading.
D—Air Flow Controller maintains a definite relation between metered volume of draft (draft differential) and air loading pressure.
E—Fuel Feed Controller maintains a definite relation between metered fuel supply (feeder speed using electric tachometer) and air loading pressure.
F—Fuel-Air Ratio Rheostat for changing relation between fuel and air supplies.
G—Furnace Pressure Controller maintains furnace pressure at desired value.

1—Air Compressor supplies air for automatic control loading lines to all boilers controlled.
2—Pressure reducing valve.
3—Air loading lines to other boilers.
4—Steam header pressure connection.
5—Feeder speed control.
6—Electric tachometer.
7, 8—Damper or vane drive units.

portional to coal feeder speed. Electric tachometer 6, linked to the feeder drive shaft, generates a voltage proportional to feeder speed. Two stationary solenoids are connected in series with two solenoids on the controller balance arm and with the tachometer, so that a force proportional to the square of fuel-feed is applied to the balance arm in opposition to the master force proportional to the square of steam demand. Thus, there results a direct proportioning of fuel-feed to steam demand. Contacts on the balance arm actuate feeder speed controller 5 (rheostat, variable speed transmission, or other device) as required to maintain balance. For certain air-swept pulverizers and for other types of fuels, a controller of the pressure-bell type, similar to the air-flow controller, is used.

A similar action is employed for air-flow control, except that the force representing metered air supply is obtained by means of two oil-sealed pressure bells responsive to draft drop across a section of the boiler. Contacts at the controller (D in Fig. 1) actuate an electric motor drive-unit at the induced draft damper. Since draft drop is proportional to the square of combustion air-flow, and is balanced against a loading pressure representing the square of steam demand, a predetermined ratio is maintained between air and steam flow.

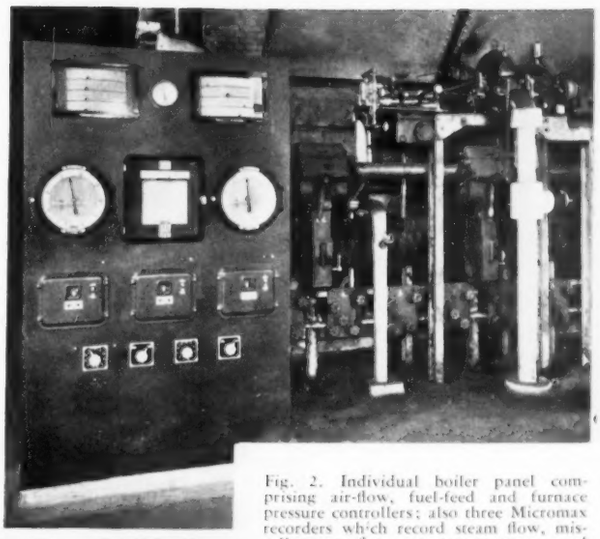


Fig. 2. Individual boiler panel comprising air-flow, fuel-feed and furnace pressure controllers; also three Micromax recorders which record steam flow, miscellaneous flue gas temperatures, and CO_2. (Master controller is located on another panel.)

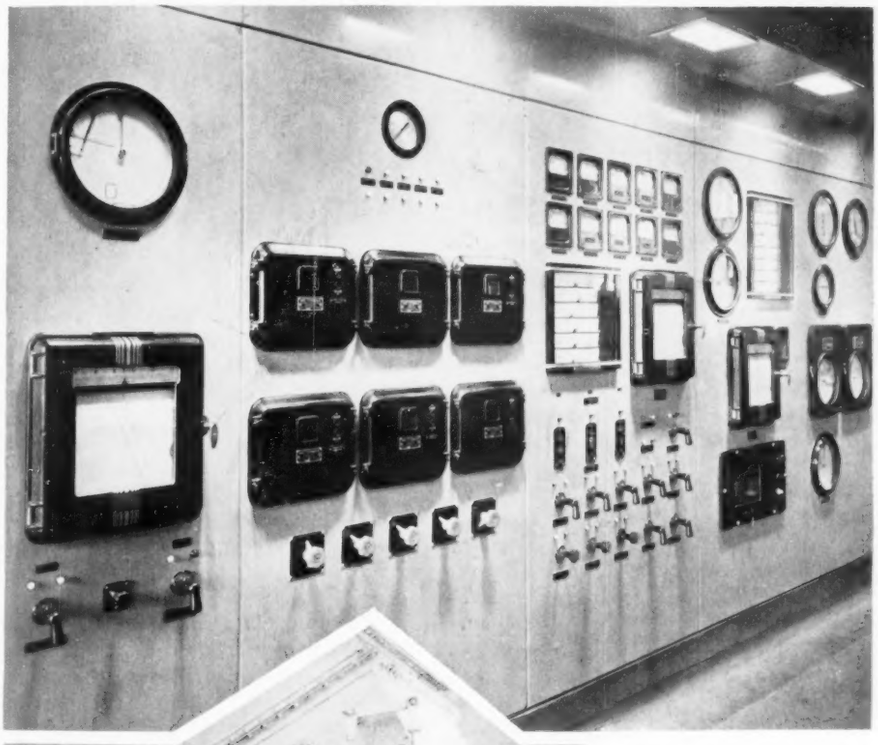


Fig. 3. From this combined Metermax control and instrument panel is regulated the combustion of a high-pressure boiler fired by three unit coal pulverizers. Metermax panel section is second from left. At top are loading pressure indicating gage and signal lights showing limits of travel for motor drive units. Just below: furnace pressure, master and air-flow controllers; with the three pulverizing mill controllers beneath. The row of control knobs regulates: load adjustment valve; transfer valve (master or individual automatic); selector switch (automatic or push-button); fuel-air ratio adjustment; and mill selector valve (adapts control action to one, two or three mill operations). Controller at extreme left regulates steam temperature. The two Micromax recorders at right of center indicate and record feed water and mill air temperature; air and fuel-gas temperature.

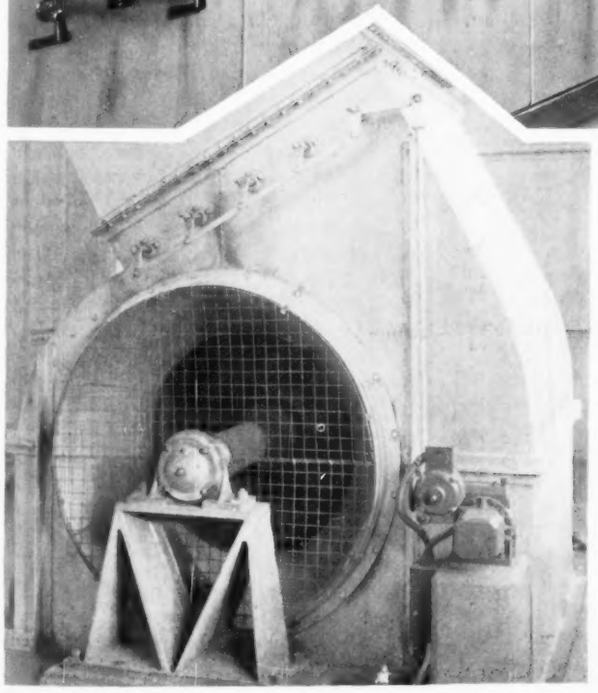


Fig. 4 (left). L&N forced-draft damper motor drive unit commanded by Metermax control.

Fuel and air are both balanced against the same air-loading pressure and are thus held in predetermined relation to one another. When desired, this relation can be adjusted by means of a fuel-air ratio rheostat, connected in series with the electric feeder tachometer.

The furnace pressure controller resembles the air-flow controller, but has only a single pressure bell, and adjustable loading weights in place of the air-loading diaphragm. An electric drive-unit at the forced draft damper responds to the controller contacts.

Each controller provides selective contact action, whereby drive-unit response depends upon the extent of controller unbalance. These contacts act in combination with a central motor-operated interrupter or contact timer, which supplies current impulses of adjustable

duration. The overall action is such that a large unbalance results in fast drive-unit travel; small unbalance, in slow travel.

By means of two manually-operated control valves in the air-loading line at each boiler, the operator can select the type of individual controller action he needs. A transfer valve, when in "master" position, permits loading pressure to be transmitted from the master controller to the individual boiler line, thus providing full automatic control. An alternative "individual" setting of this valve transmits constant air pressure directly from the supply unit to the boiler line. A load adjustment valve then permits the individual boiler loading pressure to be reduced to any desired extent below the transmitted value from either source, providing for biasing of boiler outputs on "master" control and determining the constant boiler output which will be maintained at the "individual" setting.

Push buttons are built into the case of each controller. By turning a single selector knob at each boiler panel, the operator disconnects current-supply to all controller contacts, thus immediately making available this remote control for use during any temporary abnormal condition, or when bringing a boiler up from bank.

While this presentation has been necessarily brief, it should serve to bring out the basic principles of Metermax, in accordance with which each controlled variable is continuously metered and adjusted so as to keep it in balance with an air-loading pressure representing steam or heat demand.

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one with the other. A change in the pressure of any factor under control, namely, steam, fuel, air, or furnace pressure, will disturb the balance of the control beam, closing the electric contacts. This causes the control to readjust the valves or the dampers, correcting the relations between these pressures.

Below the control units in the control cabinet is a selector switch of the rotating four-position type: "OFF," "MANUAL," "SEMI-AUTOMATIC" and "AUTOMATIC."

When in the "MANUAL" position, the motorized units may be operated by means of switches on the control units.

When in the "SEMI-AUTOMATIC" position, the circuits controlled by the forced-draft control unit and the induced-draft control unit are energized. If, with the selector switch in this position, the fuel input is increased or decreased by manual operation of the fuel input control switch, the control will automatically adjust the forced draft air pressure and furnace pressure to their correct relation to the fuel pressure.

For safety, the control is provided with a thermal overload circuit breaker which instantly opens all control circuits, stopping the operation of the control should the motorized fuel valve or damper-operating mechanisms fail. When the circuit breaker opens, it leaves the fuel valve and dampers in the last position of adjustment. An alarm is operated when this circuit breaker opens.

The Valveless System

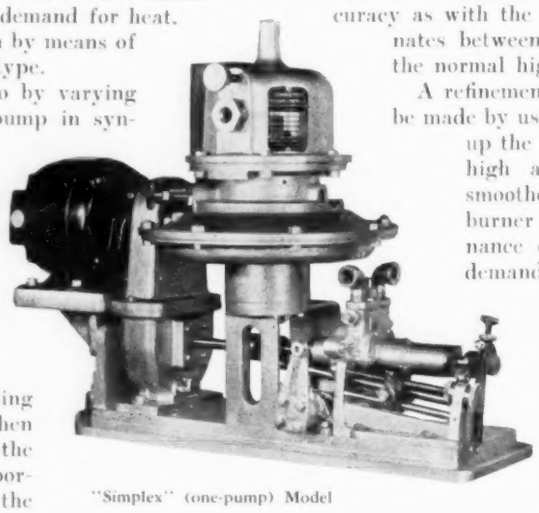
By E. L. KROON

Assistant Engineer, Johnston Mfg. Co.

IN designing the Johnston system, the aim was to approach the ideal of maintaining a perfect balance between the heat required and the heat delivered, and still using the heavy, viscous, low-cost fuel oils. Johnston Valveless automatic controllers perform three functions: (1) to feed heavy oil without interruption or variation; (2) to maintain the oil-air ratio uniform through the range of burner adjustment; (3) to hold the burner continuously in balance with the demand for heat.

They perform the first function by means of a metering pump of the positive type.

They maintain the oil-air ratio by varying the stroke of the oil metering pump in synchronism with the movement of the air regulating valve at the burner. A rod connecting the control machine to the burner ties the power diaphragm and oil regulating levers on the burner so that all operating parts move together in the correct ratios to maintain the oil and air delivery in proper proportions. This permits adjusting the oil-air ratio at "low" and then at "high" delivery after which the machine will maintain the proportions automatically through the whole range of variation in delivery.



"Simplex" (one-pump) Model

Maintaining heat balance is performed by automatically varying the delivery of oil and air in proportion to variations from the control setting of an element responding to the instantaneous demand for B.t.u's. In most applications this "master" element is a pyrometer. Since variations in the furnace temperature lag behind variations in B.t.u. supply, and variations in thermocouple temperature lag behind the furnace, it is necessary to anticipate the effect of changes in burner delivery. This is accomplished in our floating system by an anticipator which operates to neutralize the effect of lag. Anticipators are of several types, but all operate by changing the position of the controller in advance of the normal time.

For applications where it is not always necessary to maintain extreme accuracy, the two-position valveless controller maintains the oil-air ratio with the same accuracy as with the floating control but merely alternates between the high and low setting as in the normal high-low system.

A refinement of the two-position control may be made by use of our anticipators. These speed up the frequency of alternations between high and low so that variations are smoothed out by rapid alternations in burner delivery instead of by maintenance of a continuous balance between demand for and supply of heat.

The floating control requires direct mechanical connection between the controller and the burner to maintain exact synchronism between the oil and air adjustments.

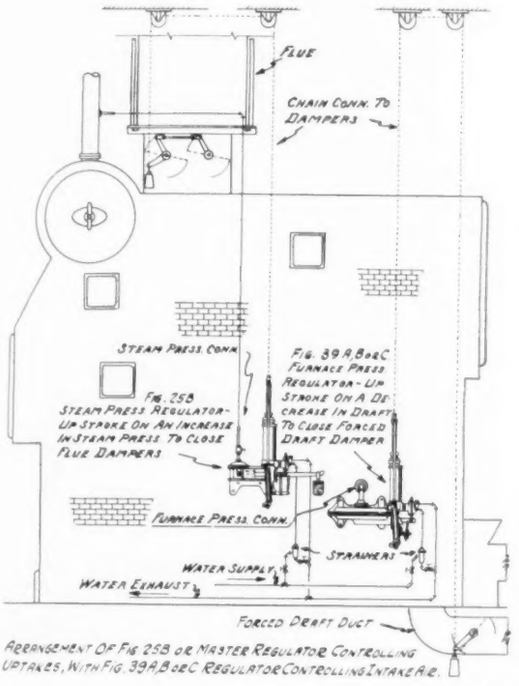
The two-position controls are somewhat more flexible in this respect as they can be hooked up direct the same as the floating controls, or may be located in any convenient location and connected to the burner by the oil delivery pipe and by an air pipe to a diaphragm on the burner by which the air valve in the burner is shifted between high and low.

Although the method used to shift the controller varies with these different types, the above-described valveless system is a fundamental part of each design. This insures the maintenance of oil-air ratios with heavy oils.

The R-K System

By LINWOOD KIMBALL
Engineering Dep't, Ruggles-Klingemann Mfg. Co.

ONE of the many arrangements possible with the Ruggles-Klingemann system of automatic combustion control is shown in Fig 1. It represents a simple installation (of master regulator and furnace-pressure regulator) on coal-fired boilers, with constant-speed fan.


FLUE
CHAIN CONN. TO DAMPERS
STEAM PRESS. CONN.
FIG. 39 A, B OR C FURNACE PRESS. REGULATOR - UP STROKE ON A DECREASE IN DRAFT TO CLOSE FORCED DRAFT DAMPER
FIG. 25B STEAM PRESS. REGULATOR - UP STROKE ON AN INCREASE IN STEAM PRESS. TO CLOSE FLUE DAMPERS
FURNACE PRESS. CONN.
STRAINERS
WATER SUPPLY
WATER EXHAUST
FORCED DRAFT DUCT

ARRANGEMENT OF FIG 25B OR MASTER REGULATOR CONTROLLING UPTAKES, WITH FIG. 39 A, B OR C REGULATOR CONTROLLING INTAKE AIR.

Fig. 1

If the fan is turbo-driven, the chain shown connected to the forced-draft duct damper can be connected to a chronometer valve (described below). If the fan is driven by a variable-speed motor, this chain can be connected to a dial switch.

In cases of fuel-oil, pulverized-coal or gas-fired boilers, it is recommended that the controls be interlocked to prevent quick positive pressures in the furnace.

The master regulator is connected to the boiler pressure header, and any pressure change causes this regulator to vary the uptake dampers. The movement of the uptake dampers changes the pressure in the furnace and the furnace-pressure regulator, responding in this change, varies the position of the damper in the wind duct, to increase or decrease the air flow through the fuel bed and restore the pressure over the fire to normal setting.

This type of combustion control compensates for variations in the thickness of the fuel bed.

One master regulator may control a battery of boilers, but one furnace regulator is recommended for each boiler so that no one boiler will hog the load.

This combination will hold steam pressures within 2 lbs. and will maintain overfire within 0.02" of water.

The R-K "25-B" master regulator, Fig. 2, incorporates the R-K step action, whereby the damper is opened in steps, and after each step or movement of damper, the regulator comes to rest, to allow the change to become effective, or to get further pressure changes. It prevents over-travel and hunting. It embodies means for changing operating range to conform to requirements.

The furnace-pressure regulators are made in three types: (1) the "39-A" which also incorporates step action; (2) the "39-B" which is of the floating type, desirable when overfire is desired to be kept constant over entire boiler rating, as when furnace regulator controls the uptakes instead of the intake air as shown; (3) the "39-C" with hydraulic cylinder remote from the regulator, desirable when it is preferable to put the regulator on the wall and the hydraulic member near the damper.

Fig. 2

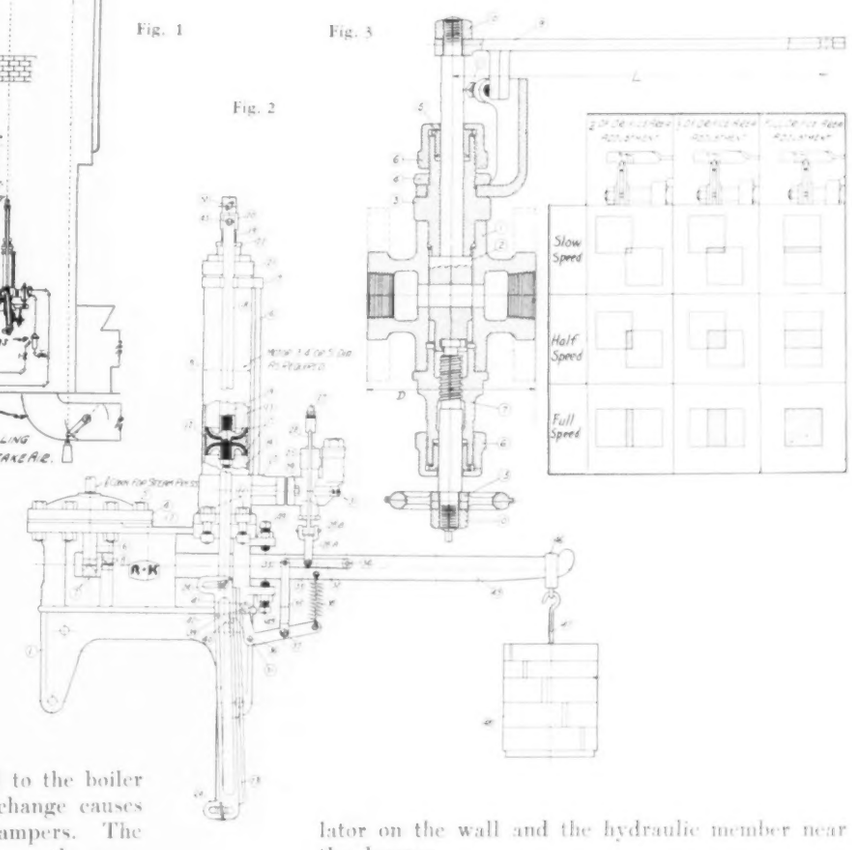


Fig. 3

All regulators are hydraulically operated, water or oil being found advantageous in that they apply power immediately and do not cause drift and over-correction by any expansive force.

These regulators are extensively used for controlling the speed of motorized units used in connection with this automatic combustion control.

The adjustable chronometer valve, Fig. 3, is recommended for regulating the speed of balanced-draft system steam-driven units. Its orifice area being adjustable from zero to full port opening, the proper flow area can be obtained to produce uniform speed variations, eliminating the tendency of over-correction of speed of steam-driven units.

The Shallcross System

By CARL SCHINDLER
Chief Engineer, Shallcross Controls, Inc.

INSTEAD of complying exactly with the editor's request for a description of "the" Shallcross System of automatic combustion control, we shall describe one installation (Buffalo Sewage Disposal Plant, Buffalo, N. Y.) which is fairly typical—and which is certainly interesting.

This system is completely electrically operated. It was designed to meet requirements stated as follows:

"(1) It must replace the services of a good operating engineer and in doing so, it must be on the job every moment during plant operation. It must be responsive to much smaller changes in combustion conditions than can be possible under manual control.

"(2) It must put fuel into the boilers in exact proportion to the load demands.

"(3) It must measure the flow of fuel to the boilers and put in combustion air, always in the right proportion.

"(4) It must adjust the stack dampers to burn this mixture of fuel and air at the highest economy."

This system performs these functions automatically. In addition it permits the operator to add a personal element whenever necessary; and gives alarms when radical changes or emergencies take place.

The plant consists of two boilers rated at 225 h.p. each, only one being fired automatically at a time. The boilers are fired by two Peabody combination gas and oil burners, the system firing all the sludge gas that is available from the plant and automatically supplementing this with fuel oil whenever the plant load is not satisfied by the sludge gas. The burners are of the circulating type, a constant amount of oil being supplied by the system for each burner at all times, the residue not being required for fuel, being returned. Each boiler is equipped with an individual fan with divided air ducts, duct G supplying the controlled amount of air for the gas; the second duct O supplying the air for the oil.

Complete alarms and indicators are included in the system.

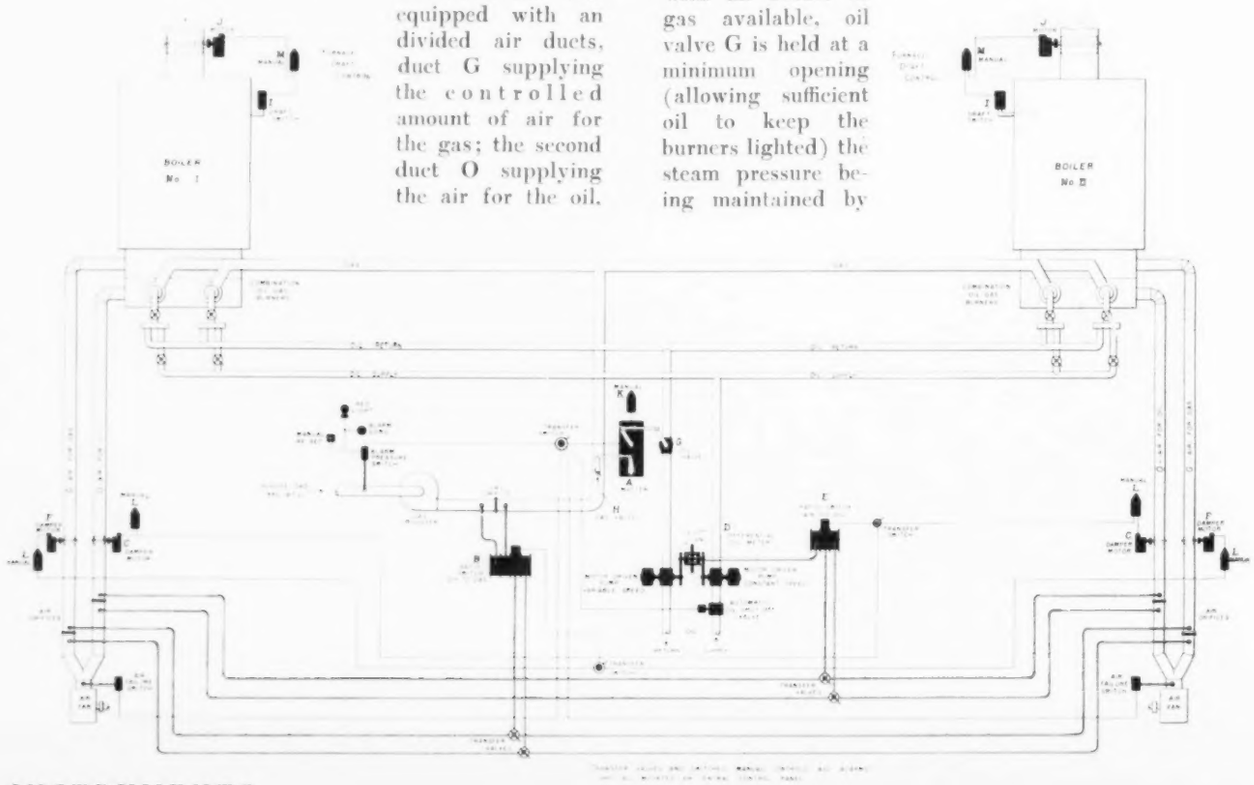
The oil to the burners is measured over a differential meter D. This meter consists of two motor-driven positive-displacement oil pumps, one pump delivering the constant flow of oil to burners and the other pump being driven by a motor at a speed proportional to the rate of flow of the returned oil. The two pump motors are joined, through a differential gear, to a revolving pilot fan which delivers a suction to the control system, this suction being a measure of the difference of the amount of flow of the two oil lines.

This pilot fan suction is delivered to a ratio switch E, which is actuated by differential pressures from an orifice in one of the air lines O, the two being balanced in an adjustable ratio, one to the other, the switch actuating motor-driven damper C in the air line O.

The sludge gas is measured over an orifice, the differential of which is led to ratio switch B. This ratio switch is also energized by differential pressures from the orifice in air duct G, the two sets of differentials being balanced against each other at an adjustable ratio in the ratio switch. The ratio switch actuates motor driven damper F in one of the air ducts G, maintaining a definite ratio of combustion air to gas.

The system thus measures the flows of both gas and oil and delivers a total amount of air to the boiler, whatever the ratio of oil to gas, and in an amount proper for the requirements of each fuel.

Master A, actuated by the steam pressure, contains two motor drives, one actuating gas valve H and the second, oil valve G, operating as follows: If the load is low with an excess of gas available, oil valve G is held at a minimum opening (allowing sufficient oil to keep the burners lighted) the steam pressure being maintained by



controlling the gas through valve H. As the plant load rises, the steam pressure drops slightly and gas valve H continues to open.

When gas valve H is wide open and the load still increases, oil valve G is then gradually opened, maintaining the steam pressure. This action continues on a rising load until both gas and oil valves are wide open at a maximum firing. On a dropping load, the reverse action takes place, oil valve G gradually closing until it reaches its minimum position, from which point the gas valve then starts to close, maintaining the steam pressure.

The furnace pressure of each boiler is maintained at an adjustable fixed amount by the furnace draft control, consisting of a draft switch I and breeching damper motor J.

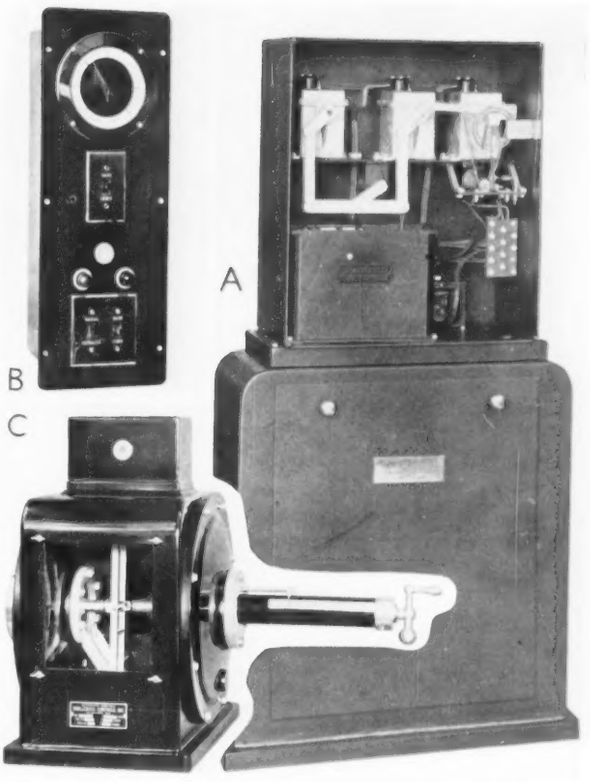
A manually-operated throw-over switch transfers all circuits of the control system to whichever boiler is under automatic control. A manual throw-over valve transfers all control piping from the ratio switch to that boiler in operation. Additional hand valves and manual control stations permit the idling boiler to be warmed up and controlled under hand control.

Adjustments. The maintained steam pressure is adjustable on master A. The air-gas ratio is adjustable in ratio switch B and that of air to oil in ratio switch E. The maintained furnace draft is adjustable on each furnace draft switch I.

Manual Controls permit either automatic operation or hand setting of all units of the controls. Manual station K permits the master to operate automatically, adjusting gas and oil to the load, or permits the rate of firing of each fuel to be set at a fixed amount independent of the steam pressure. Manual stations L on the air dampers permit automatic operation of the setting of the air flow manually—for warming up the idle boiler, for example. Manual stations M on the draft control are used for opening the dampers when blowing soot, etc.

All these manual control stations, together with the throw-over valves and switches, are mounted together at the main instrument panel.

Indicators. Light signals are provided at each manual station, which show whether each particular control is alive or dead, whether it is on manual control or on automatic and, when on the latter, showing whether that particular controlled function is high and being lowered, is low and being raised, or is normal.



A—master control; B—manual control station; C—adjustable-ratio switch.

Safeguards. An alarm is provided to sound when the sludge gas pressure at the inlet of the gas booster has dropped below a predetermined safe limit. This alarm rings continuously and a red light flashes until an operator has taken action and silences the gong on a push button. This alarm also shuts off the gas but permits the oil to flow. An air failure switch on each air fan outlet closes an automatic shut-off valve in the fuel oil line if the air should fail from stoppage of the fan, etc. At the same time, master A closes the gas valve, thus preventing the boilers from being flooded with either oil or gas if the air fails.

The Smoot System

By CHESTER R. EARLE
Engineer, Republic Flow Meters Co.

SMOOT automatic combustion control systems are tools to aid the boiler operator, not devices to replace him. They enable him to operate the boiler plant at test efficiencies, by performing for him the repetitive routine adjustments of fuel supply and air supply necessary to maintain efficient combustion over the load range and to maintain the steam pressure constant. They maintain any desired fuel-air ratio but allow the operator to change this ratio to conform to changes in the quality of fuel and other variables. They also permit the operator to change the boiler from automatic to manual control instantly without affecting operation.

In a Smoot automatic combustion control system a master controller, in accordance with variations in steam header pressure produced by variations in steam demand, sends air loading pressures to oil-operated or air-operated regulators which measure the variables they control and adjust the various units of combustion equipment in accordance with the master impulses to supply the required fuel and air in the correct ratio over the load range.

To vary the fuel supply, the fuel-feed regulators operate motor rheostats, turbine steam valves or variable speed transmissions, primary air and coal-carrying air

THE SMOOT SYSTEM

Continued from page 251

dampers or fuel-oil or gas supply line valves. To control flow of air and flue gas through the boiler, the air-flow regulator operates uptake dampers, induced-draft fan vanes or dampers or varies fan speed by operating motor rheostats, turbine steam valves or hydraulic couplings. To maintain constant furnace pressure, the furnace pressure regulator controls forced draft by operating similar control devices. This regulator is responsive to furnace pressure only but must be coördinated with the system since it is affected by fuel and air flow changes. A typical Smoot combustion control system is shown in Fig. 1.

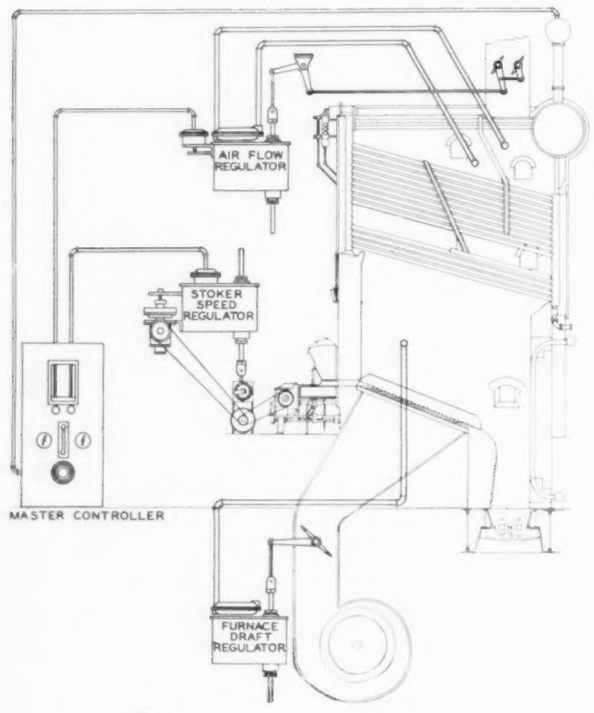


Fig. 1

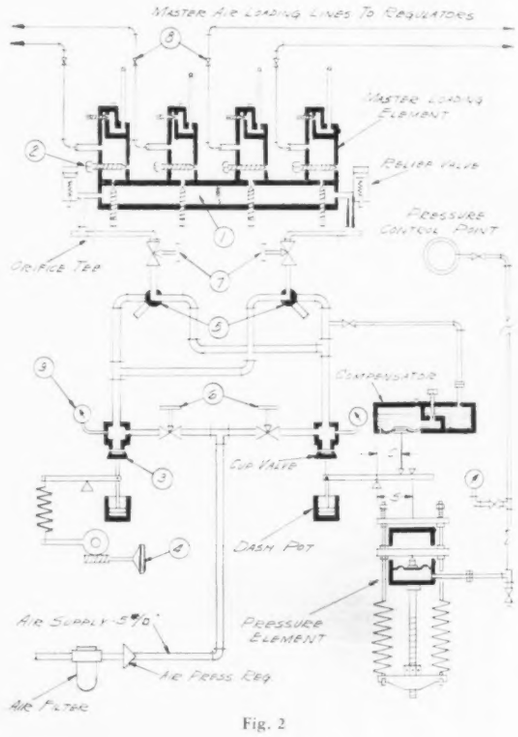


Fig. 2

A typical master controller arrangement to control two groups of two regulators each is shown in Fig. 2. The pressure element transfers any change in the controlled pressure inversely into a change in the air loading pressure in the air manifold by movement of the air bleed cup valve. The air loading pressure, transmitted to the master loading element of each regulator to be controlled, is adjusted by ratio adjusters 2. The ratio of pressures between elements remains fixed for each adjustment of the ratio adjusters. The air pressure change in manifold 1 is common to each section. The result is an equal percentage of air pressure change in each master loading section.

Each master loading element is equipped with an indicating mercury manometer.

From the diagram, Fig. 2, it is seen that if the main header pressure drops, calling for an increase in fuel and air supply, the steam pressure element diaphragm moves down, closing the cup valve to increase the loading pressure to the regulators, causing them to supply more fuel and air. The compensator superimposes on the cup lever a loading pressure, proportional to the master tunnel pressure and applied through glycerine that flows gradually through an adjustable orifice. Thus the compensator gradually returns the pressure to its original value after an increase in steam demand.

To change the boiler from automatic to manual control, valve 5 is turned 90 degrees. This places the fuel and air regulators under the control of a manually-operated pressure element.

With the Smoot system of combustion control, either hydraulic type or pneumatic type regulators are used.

Since the operation of these regulators is fundamentally the same except for the different operating medium, only the hydraulic type shown in Fig. 3 will be described. This regulator consists of a measuring element, an amplifier element, a stabilizing element and a power element. The diaphragm of the measuring element is connected by a push rod to the weighbeam, which, through the guide beam, is connected to the multiplying valve stem. The amplifier piston, the top area of which is half the bottom area, is connected by linkage to the pilot valve. Oil under pressure is admitted through an adjustable orifice to the amplifier chamber under the amplifier piston and to the space above the piston, oil from below this piston draining through the multiplying valve.

When the regulator is in equilibrium, the weighbeam is horizontal and the multiplying valve in such a neutral position that the oil pressure on the top of the amplifier piston balances that on the bottom, holding it stationary and thus holding the pilot valve and power cylinder in neutral position. If the pressure increases above the measuring element diaphragm, this pressure pushes down on the weighbeam. This movement, through the guide beam, is transmitted to the multiplying valve, causing it to close and restrict the flow of oil under the amplifier piston, causing the latter to move up. As it does so, the linkage moves the pilot valve down, admitting oil pressure to the top of the power cylinder and causing the power piston to move down, the oil below the piston flowing to the drain.

If the pilot valve remained open, the power piston would continue moving to the bottom of the cylinder, but, as the power piston moves down, it actuates the return motion linkage, which is connected to it by a simple rod or cable system, causing the pilot valve to return again to neutral position and stopping the power piston at the new control position. By this method, the power piston is made to follow accurately the detections of the measuring element.

The regulator has a hand operating lever with which the operator can position the power piston by utilizing the powerful hydraulic system.

The stabilizing dash-pot on the amplifier piston exerts on guide beam and weighbeam a force opposing the

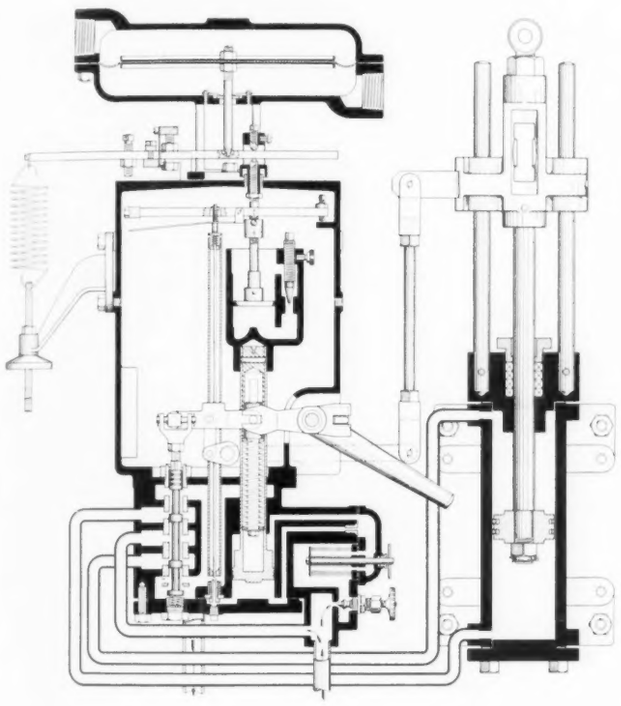


Fig. 3

downward force of the measuring element and tending to restore the weighbeam to balance. As the amplifier piston moves up, its motion increases the oil pressure under the dash-pot plunger. As this oil pressure is gradually relieved by the passage of oil through the adjustable orifice, the upward force on the weighbeam gradually decreases. Adjustment of the orifice controls the dash-pot action, which produces a regulator speed proportional to the deviation of the controlled pressure, thus preventing the regulator from hunting. For applications of the regulator where storage or inertia introduces a considerable time lag into the system, a picard spring, instead of a rigid stem, connects the dash-pot plunger with the weighbeam, producing a regulator action that nullifies the affects of the time lag. The regulator weighbeam always returns to equilibrium in the same horizontal position, without position characteristics to affect its sensitivity.

These operations have been described as if they occurred step by step, but actually they occur almost simultaneously and in synchronism.

The standard Smoot hydraulic or pneumatic regulator is built in such a way that it can be equipped with remote hand control upon installation or at any time thereafter. This remote hand control provides a method by which regulator and controlled device can be manually controlled by the operator at any distance from the control point. The remote hand control mechanism in the regulator is connected to a remote control sub-panel at the boiler control board in such a way that, by a simple adjustment, the multiplying valve of the regulator is removed from the influence of the measuring element and instead is placed under the control of a loading pressure adjusted manually by the operator.

Regulators for controlling fuel feed, air flow or furnace draft are identical except in the manner of application and in the measuring elements used. For the control of air flow, the differential pressure across a boiler is impressed on a differential element and the master loading pressure from the master controller on another element, the two balanced on the weighbeam against each other so that a change in the master loading pressure operates the regulator to control a damper, fan vanes or motor or turbine speed to vary the air flow. For control of stoker or pulverizer feeder speed, a speed governor control element deriving its speed from the controlled element consists of an oil chamber in which a stationary disk is suspended by a rod connected to weighbeam of the regulator. As the chamber rotates, centrifugal force produces across the disk a pressure differential that is balanced on the weighbeam against master loading pressure. An increase in loading pressure will depress the weighbeam, causing the regulator to increase fuel feed. As the governor increases speed, the down force on its disk increases to balance the weighbeam again and stop the regulator.

The foregoing explanations refer to the system for controlling one boiler. If the load is distributed between two or more boilers controlled automatically, each may have a master controlled in turn by a supermaster for the battery. If there are several batteries, each may have a sectional master controlled in turn by a supermaster for all. By this method, any individual boiler unit may be operated at a fixed rating (by transferring it to manual control), may carry a proportional share of the load, may fluctuate between maximum and minimum rating (by use of maximum and minimum devices) or may be cut out entirely.

Under any of the above-described methods of operation, the fuel-air ratio for the individual boilers may be maintained irrespective of the method of operation, but this ratio may be changed as desired. With the supermaster system, any boiler or boilers may be put on base load independently of the others.

In some instances, it may be desirable to hold boiler rating within maximum and minimum limits. This is done by devices that limit the maximum and minimum variations in master loading pressure. Within the limits, these controls have no influence on the operation; they function only when those limits are exceeded.

When boilers are fired by more than one fuel—for example, blast furnace gas as the base fuel and coal or oil as supplementary fuel—the make-up fuel must be controlled to meet any deficiency of the base fuel. To do this, the total air must be proportioned to the sum of the air requirements of the two fuels. These operations are carried out by the Smoot totalizing master controller, which maintains the relation between the master loading pressures to the two fuel regulators and to the air regulator in such a way that the ratio between total air and the sum of the air requirements of the two fuels is constant at all times. The master controller also maintains the basic fuel demand within the basic fuel supply.

The Westinghouse System

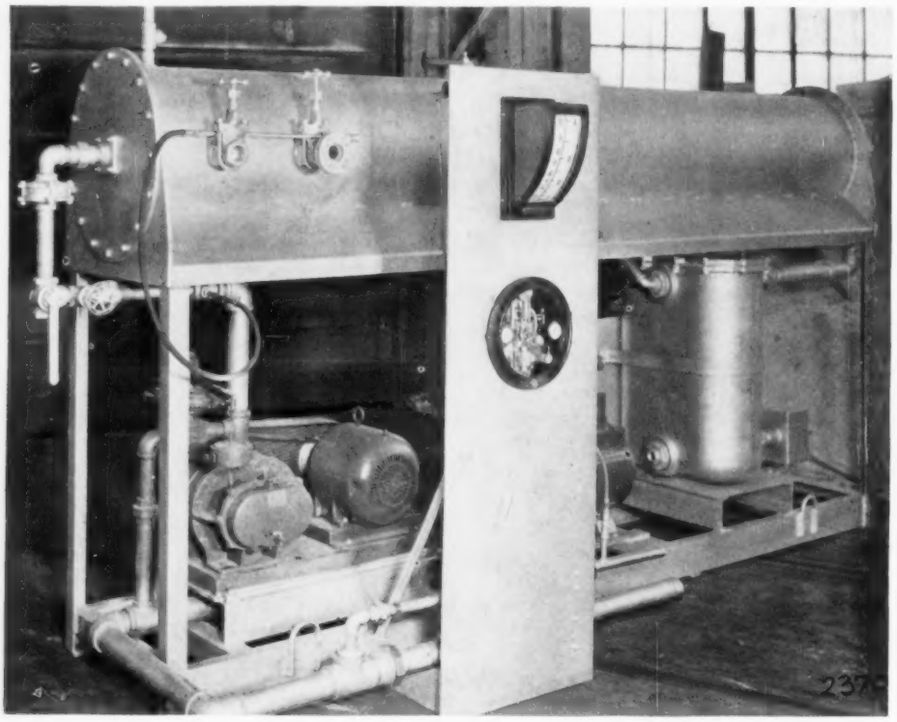
By C. E. PECK

Heating Section Engineer, Westinghouse Electric & Mfg. Co.

FOR applications such as bright annealing and scale-free hardening, gas atmosphere equipment is necessary to provide the desired atmospheres in metallurgical furnaces. Under ordinary operating conditions of fluctuating pressures and variable flow demand on the atmosphere equipment, automatic control of combustion ratio is necessary in order to insure a reasonably constant gas atmosphere composition on the outlet side of the producing equipment. The automatic ratio control scheme used should fulfill the following requirements:

(1) Single-valve control, that is, the control of flow demand from one manual regulating is desirable.

(2) The control should not be affected by small dirt or dust particles which might be present in the incoming gas and air lines.



(3) The automatic ratio control instrument should be preferably separate from the pumping and flow measuring equipment, so that operation may be carried on even though the automatic control is not in operation.

In Westinghouse gas atmosphere producing equipments the air and gas flows are automatically proportioned by means of a Bailey air-operated flow-ratio controller. The mixture is pumped to a burner located at the end of the horizontal catalyst-filled combustion chamber. In this chamber, the gases are cracked and form the atmosphere used in the heat-treating process. For bright annealing and scale-free hardening of ferrous materials, the atmosphere from the unit corresponds to a partly combusted fuel gas; its exact composition depends on the type of fuel gas used. For bright annealing non-ferrous materials such as copper, the atmosphere corresponds to a completely burned fuel gas with a slight deficiency of air, so that no oxygen is present in the final products of combustion. The water vapor in the gas is condensed out, down to a dew-point corresponding to room temperature conditions.

As illustrated, a typical equipment to produce these atmospheres consists of flow-measuring instruments, automatic ratio control instrument, gas-air mixture pumping equipment, burner and catalyst-filled combustion chamber and tube type surface condenser to remove moisture of combustions. Such equipments are commercially available in sizes ranging from 200 to 15,000 ft.^{3}/hr.

The air and gas flows necessary are measured, regulated and proportioned in the proper ratio ahead of the blower. The air flow and the gas flow are individually measured on indicating type orifice meters. The diaphragm-operated valve in the gas line is operated by means of compressed air from the ratio controller. If the flow demand on the system changes due to closing of valve beyond the exit side of the blower, the air and gas flow rates ahead of the blower will of course also change. The consequent change in the pressure drop across the orifice which measures the air flow is transmitted to a positioning diaphragm inside the ratio controller. This change causes the air pilot valve to position the large diaphragm-operated valve in the inlet gas line, thereby maintaining the original air-gas ratio setting. This type of controller is sensitive to extremely small changes in flow rates and will maintain combustion ratio over the entire flow range shown on the meters.

In applications (rather infrequent) where the quality of the incoming fuel varies, the automatic control of air-gas ratio on the inlet side of the atmosphere producing equipment will not necessarily produce a constant quality of gas on the outlet side of the equipment. A combustible analyzer equipment (various types commercially available from several manufacturers) is then employed to control a valve in the inlet gas line ahead of the atmosphere producing equipment, so that the products of combustion are constant even though the composition of the inlet gas used as a fuel would vary.

This is an INVITATION

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CONTEST

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Conducted by Richard Rimbach, Publisher of *Instruments* (The Magazine of Measurement and Control), 1115 Wolfendale Street, Pittsburgh.

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If you are not employed by an instrument manufacturer you are eligible for entry. The subject is "an unusual application of a standard instrument or control device" and, surely, YOU know of such an application! So lose no time and send for an entry blank. Write to Scientific Apparatus Makers, 20 N. Wacker Drive, Chicago, or to Instrumentation Contest, 1115 Wolfendale St., Pittsburgh, Pa. Or ask the instrument-company engineer who calls on you. But do it now, because THE CONTEST CLOSES NOVEMBER 15.

THE MONTH'S NEW INSTRUMENTS

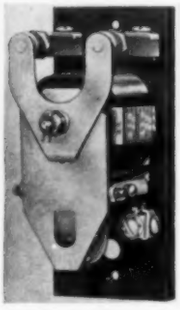
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Heavy-duty Relays

"Bulletin 132" relay has been developed for heavy duty service on a-c. and d-c. circuits. Large-gap, silver-to-silver, self-aligning contacts with adequate surfaces and pressures to break 30 amps. and insulating material to withstand 2500 volt dielectric test make these relays suitable for light contactor duty. The "Y" type contact arm uses a large coil spring for pressure as in contactor construction. If required, blow-outs can be furnished. These relays are available with normally open or normally closed contacts. Double-pole with common feed and single-pole contact combinations can be furnished. They are listed for 6, 12, 24, 32, 115 and 230 volts a-c. and d-c.—*Ward Leonard Electric Co., 38 South St., Mount Vernon, N. Y.*



Arc Rectifier

New rectifier for spectro-chemical analysis work has been designed specifically to supply d.c. for operation of an arc; utilizes a 110-volt a.c. and employs transformer and rectifier tube to give 250 volts d.c. at no load. A reactor in primary circuit, operated from a hand-wheel, varies output current from 4 to 14 amps., voltage adjusting itself to the drop across the arc. A voltmeter and ammeter are included, as is an electric timer which can be set for any value from 0-3 min. and various switches for putting timer in and out of circuit, reversing polarity of the arc, and turning the arc circuit on and off.—*Applied Research Labs., 1208 San Julien St., Los Angeles, Calif.*

Radio Tester

Known as the "Trouble Shooter", this new instrument has a multi-scale d'Arsonval 0-1 milliameter, accurate to 2%. It measures d-c. volts: 0-5 / 0-50 / 0-500 / 0-1000 at 1000 ohms per volt sensitivity; d-c. milliamps 0-1/0-10; ohms 0-500/0-50,-000/0-500,000. Weight 24 oz. *Radio City Products Co., 88 Park Place, New York.*

Electric-contact Type Temperature Control

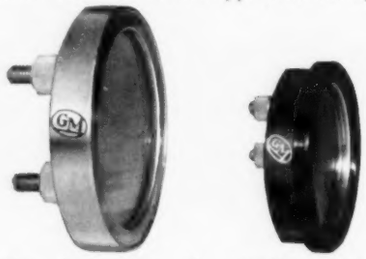
New model of "Cartridge Thermo-switch" (see *Instruments*, July, 1938 page 176) is provided with a block type head as illustrated, to permit use of flexible armored cable over the leads if application requires that protection. Also, provision is made for attaching a dial and knob.—*Fenwal Inc., 6 Main St., Ashland, Mass.*

Clock Regulator

For application to existing standard clocks (or to commoner types of clocks used as standards) a simple brake arrangement has been devised, similar to those used on stop-watches. User of clock makes sure that it runs a few seconds a week fast, and uses new device semi-weekly or daily to stop it momentarily. New device consists of crown, stem and sleeve fitted into clock case.—*General Time Service, 1507 W. Vliet St., Milwaukee, Wis.*

Barrier-type Photocell

To "Visitron" series of phototubes are added two new barrier type cells having twice the output of preceding units. "F2A" has a non-tarnishable metal case; "F3" has a Bakelite case. Both can be supplied with visual filters to give them a color response equivalent to that of the human eye.—*G-M Laboratories, Inc., 1731 Belmont Ave., Chicago, Ill.*



Damper Operator

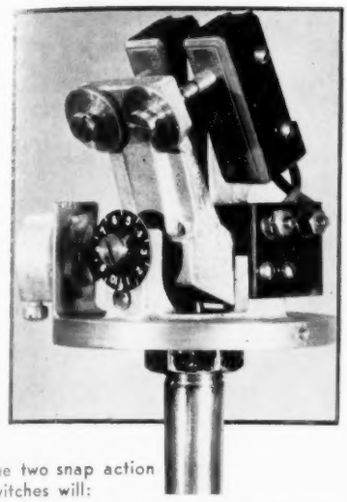
Supplementing valve-position indicators (*Instruments*, Feb. 1935, page 52) and position-indicating valves (*Instruments* Sept. 1938, page 210), maker has brought out manual operator-indicator for dampers. "Controller" is mounted on boiler front or side and operates damper by cable and quadrant. Adjustable eccentricity of quadrant permits predetermining ratio of air to dial readings.—*Tefft-Jackson, Inc., 2 Allens Ave., Providence, R. I.*

Day-night Temperature Time Switch

Announcement is made of the "Nite-Temp"—a new synchronous, self-starting electric clock switch especially suited for day-night temperature control applications. By means of this new instrument in conjunction with thermostats and effective temperature control instruments, an automatic night-time setback is provided. New switches may be located either with the control instrument concerned or in remote location—wherever a handsome electric clock would be of use as a timekeeper. Clock motors operate on 20 volts from transformers supplied with the clocks, which are in turn supplied from the 110-volt or 220-volt lines according to specifications.—*Julian P. Friez & Sons, Baltimore St. and Central Ave., Baltimore, Md.*

Multi-tester

"Model 444" a-c.-d-c. multi-tester is said to be equivalent to 22 different instruments: has a 3½" d'Arsonval movement accurate within 2%, and a multi-colored dial scale. Four a-c. voltmeter ranges up to 1000 volts; four ohmmeter ranges extend from ½ megohm down to 0.01 ohm. At 1000 ohms per volt, four d-c. voltage ranges cover up to 1000 volts. Four db ranges from —12 to +54. Three current ranges: 1, 10 and 100 milliamps.—*Radio City Products Co., 88 Park Place, New York City.*



The two snap action switches will:

A. Control heating or cooling or both.
B. Control the temperature and give either a high or low limit device.
C. Give either two or three step control.
D. Give floating control with reversing control motors.
E. Give two or three speed control of auxiliary motors.

Available for temp. —100 to 1400°F. Other models with special alloy tubes suitable up to 1800°F.

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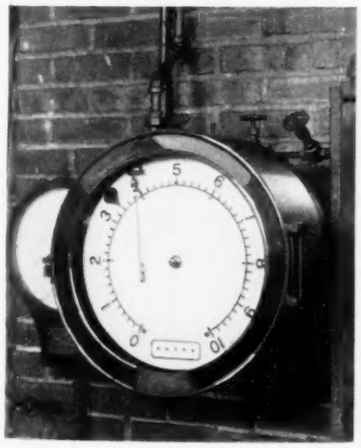
Cochrane Flow Meter Reduces Losses 40% by Detecting Leaks



A Cochrane Meter was installed to measure pump discharges in a water works system. A steady flow, recorded between 1 A. M. and 4 A. M., indicated leakage. This remedied, pumpage losses were reduced 40%. Savings were sufficient to pay for the meter **every two months.**

Cochrane Flow Meters give **accurate** measurements of fluid flow; dependable records and checks on operating costs. Write for illustrated bulletins.

COCHRANE CORPORATION
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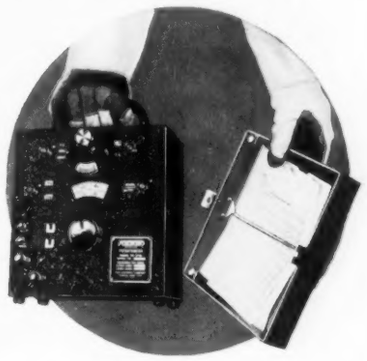
COCHRANE
FLOW METERS

Portable Pyrometer

Built primarily for temperature measurements where a permanent installation is not required, new "Model 8106" portable indicating potentiometer pyrometer is also suitable for testing and standardizing service instruments and thermocouples, for exploratory work and as a spare. Its large handle is permanently secured to all-welded aluminum case. A spring clip inside removable lid holds data sheets, etc. Scale is 17" long. Double-range instruments have two scales, both of which may be for temperature,



and for the same or different thermocouples. Each scale may be calibrated in millivolts, or one for mv. and one for temperature. Single-range instruments are equipped with one scale, either for temperature or millivoltage. It is said that "increased mechanical sensitivity is inherent in the vernier, assuring precise balancing by the vernier-type dial." Pyrometer operates either horizontally or vertically with equal accuracy. Automatic cold-junction compensation is provided by use of a cold-junction compensator coil. By reversing the coil, unit can be used as a source of emf., or for checking calibration of other instruments. A vernier-type rheostat permits standardizing the circuit quickly and precisely. Made with platinum-iridium contact points, standardizing rheostat and slide wire contact offer considerable resistance to corrosion and wear.—*The Foxboro Company, Foxboro, Mass.*

Illuminated Reading Glass

Twelve to eighteen lines of type are spanned by new large "Electric Reader."

Lamp, operable from a-c. or d-c. supply, is concealed in Bakelite housing.—*E. W. Pike & Co., Cranford, N. J.*

Now... ANALYZE FLUE GASES FOR CO_2 BY THE THERMAL CONDUCTIVITY METHOD

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Here is a small portable CO_2 Indicator or CO_2 and Temperature combined if you prefer it, that makes Flue Gas Analysis very easy. It does not require a trained chemist since readings are obtained directly by drawing the gas through the cell. No matter what your problem is, if it requires CO_2 analysis consider this instrument. It may be used on the small domestic installation or on large industrial boilers. Half the time and half the effort are required.

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CHARLES ENGELHARD, Inc.
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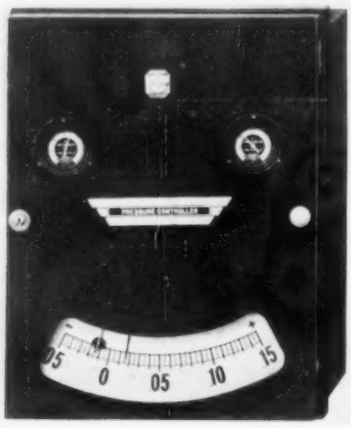
Manufacturers of Pyrometers, Resistance Thermometers, Exhaust Gas Analysers, Flue Gas Analysers, Thermocouples.

Furnace Pressure Controller

New "Air-o-Line" furnace pressure controller, applicable for controlling any pressure between —5.0 and +5.0" water column, comprises an inverted-bell type



draft indicator combined with an "Air-o-Line" control unit (see *Instruments*, Sept. 1935, page 245; Dec. 1936, page 329). Features are automatic reset and fully adjustable throttling range. It is said that this instrument has consistently held furnace pressures within ±0.002" of water on a scale span of 0.2" of water. Speed of operation: pointer will move 10% of total range in one second, 100% in three seconds.—*Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.*

Slide Comparator

New small slide comparator is readily portable and, being unaffected by water, acids or alkalis, will not warp or come apart. Color standards are enclosed in a Bakelite case so that there are no loose standards to be inserted and removed in making pH determinations, thus preventing loss or breakage from handling individual standards. Since determinations are made by sliding the color standards in front of the test sample until a color match is obtained, persons without technical training can be taught to use the set accurately with a few minutes' instruction—*W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.*

Input Transformer

New input transformer, known as the A216X, utilizes core type, hum bucking core and coil construction, encased in multi-shielded or nested outer enclosure; is suitable for operations as low as —80 db. Electrostatic shields between primary and secondary windings make transformer usable in the input circuit of high-gain amplifiers, eliminate inductive or capacitive pickup due to stray fields. Data: Primary: 50/200, 125/500 ohms; Secondary: 15,000/60,000 ohms; Operation from a line to a single or pushpull grid; Operating level —80 to +20 db; Primary unbalanced 4 mils; Primary current per leg 50 mils; Weight: 2 lbs.; Dimensions: 2¾"×2⅛"×2⅞" high.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City.*

S-M-O-O-T-H VOLTAGE CONTROL for A.C. circuits

The Type "TH" Transtat is the new continuously variable auto-transformer regulator . . . the ideal voltage control for a.c. circuits. It offers high efficiency, good regulation, great flexibility and dependable construction at moderate cost. Standard types are available for controlling voltage to single-phase and polyphase loads rated 10 Kva. and smaller, 50 or 60 cycles, 115, 230 or 460 volts. May we send you bulletin 51-1 which contains complete data?

TRANSTAT
VOLTAGE REGULATORS

AMERICAN TRANSFORMER CO.
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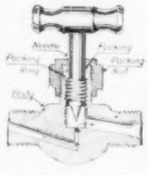

Hoke Needle Valves

Hoke Needle Valves are used mainly for easy control of small flows of fluid under high pressure, but there is also constructed a type suitable for relatively larger flows under lower pressures.

These valves are used in many laboratories, for semi-plant and plant operations, and as integral parts of various instruments and equipment made by leading manufacturers.

Standard Hoke Needle Valves are made from forged brass, cold rolled steel and stainless steel. Valves of other materials or of special construction are made on special order.

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and ask for bulletin 1210

Immersion Pyrometer

Announcement is made that the various types (straight or flexible) of "Pyro" immersion pyrometers for non-ferrous metals can be furnished with interchangeable thermocouples of various lengths, either of the bare or protected type, both being quickly interchangeable. Handle is of a new type. A correction screw on the face of the instrument makes it possible to maintain calibration. A clamping device embodied in the indicator fixes the indicating needle at the temperature indication, which may be read and checked after withdrawal. A second pressure on the red button on the housing then returns the needle to its zero setting. This locking device also protects the instrument from damage while being carried or in transit.—*The Pyrometer Instrument Co., 103 Lafayette St., New York City.*

Zero Current Voltmeter

New Model 4900-S indicates d.c. volts at infinite ohms per volt, a.c.-d.c. volts, ohms, a.c.-d.c. milliamperes, microfarads, decibels and henries. New Hickok-built square instrument has accuracy of 1%

and scale length of 4". This tester enables service men to get accurate readings of grid voltages and potentials in a.v.c. circuits without calculations, as the voltmeter shunts no current in these networks. It employs potentiometer principle and contains a built-in power supply to furnish the necessary balancing voltage—which is adequately filtered so that instrument may be connected to r.f. grids without disturbing operation of receiver.—*The Hickok Electrical Instrument Co., 10514 Du Pont Ave., Cleveland, Ohio.*

Capacitors

In a new silvered mica capacitor, the silver layer is deposited on both sides of India ruby mica by a process which bonds them at every point. Temperature coefficient of expansion of mica being "almost balanced" by its temperature coefficient of capacity, unit is said to remain substantially constant throughout its normal operating temperature range. After assembly, unit is molded in low-loss Bakelite, may further be impregnated in high-Q wax. Available in capacity tolerances of 5% down to 1%, and in capacities up to 0.001 mf., and standard d-c. test voltage of 500.—*Aerovox Corp., 70 Washington St., Brooklyn, N. Y.*

RUBICON PORTABLE PRECISION POTENTIOMETER

Available in a number of double range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. *An outstanding value.*

Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

We also make galvanometers, electrometers, colorimeters, permeameters, Wheatstone and Kelvin Bridges, Resistance standards, coil testers, acronographs, clip-on transformer ammeters.

Descriptive bulletins available on request.

RUBICON COMPANY

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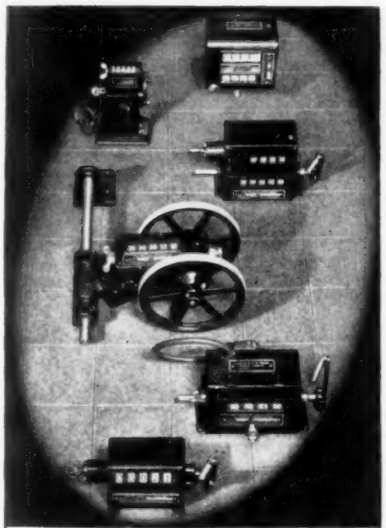
29 North 6th Street Philadelphia, Pa.



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Stroke, revolution, electric, lineal, predetermined stop counters; set-up registers, tachometers: —We have models in stock for almost any industrial use and design counters to meet special requirements.

DURANT MFG. CO.

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Combination Caliper and Height Gage

Improved feature of new Model 407R Mauser precision tool (which may be used as vernier caliper or height gage) is a combination quick-action cam lock and fine-adjusting screw. Cam lock is released by pressing the fine-adjusting screw until approximate measurement is obtained; then, in order to measure to 0.001", screw is turned while cam lock remains closed. Instrument is 9" long, with a measuring capacity of $6\frac{1}{4}$" in 0.001" and 1/128". Steel base and scriber attached to caliper jaws convert it into a height gage. It also has two knife-edges for layout work, for measuring distances between holes and for measuring root diameters of gears, threads, etc.—*George Scherr Co., 128 Lafayette St., New York, N. Y.*

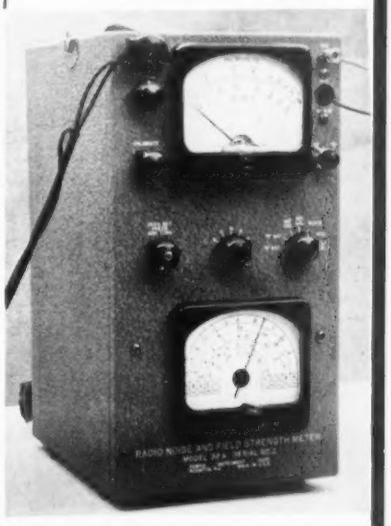
Coating-thickness Gage For All Surfaces

Original G-E enamel-thickness gage (*Instruments*, Dec. 1935, page 341) was designed primarily for use on flat surfaces. In new model, two contact disks on head, resembling the raised ends of a spool, both meet coated surface regardless of small irregularities or a moderately curved surface. Readings of the two contacts are automatically averaged. New gage can measure 0.0001" coating on steel sheet 0.007" or more. With coating thicknesses of 0.005" or greater, accuracy is 2%. Sheets of paper, celluloid, etc., can be fitted to an iron or steel plate. Circuit is such that scale is spread out at low region.—*General Electric Co., Schenectady, N. Y.*

75-watt Rheostat

New "Model G 75-watt power rheostat-potentiometer" has shaft and bushing assembly insulated from electric circuit by a ceramic driving hub; can be mounted directly upon metal panels without further insulation. Its dimensions and rating fill in between maker's 50- and 100-watt rheostats: diameter $2\frac{3}{4}$", mounting depth $1\frac{3}{4}$". Regularly supplied to mount on panels up to $\frac{1}{4}$" thick. Optional features: tapered windings, off-positions, toggle switches, cages, tandem mountings, etc.—*Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*

RADIO NOISE and FIELD STRENGTH Meter



FERRIS MODEL 32

A universal microvoltmeter for measuring all types of radio noise or radio carrier fields. Compact, portable, accurate, and useful in both field and laboratory measurements.

- For noise surveys, field intensity surveys, measurements of noise voltages on conductors.
- For acceptance tests of electrical equipment, design of noise reduction equipment, and tests on filters.
- Frequency coverage, 150 to 350 and 550 to 20,000 kilocycles.
- Input voltage range 1 to 100,000 microvolts. Field intensity range 2 to 200,000 microvolts per meter with half-meter antenna supplied.
- Self-calibrated with built-in calibrating generator, to make real measurements instead of mere comparisons.
- Output meter has three-decade logarithmic scale. Tests show this to be the only type of meter satisfactory for practical use.
- Standard power supply, dry batteries. Interchangeable packs for storage battery or 115 volt line operation.

Write for DATA

- Descriptive bulletin I-32 will be sent on request. Bulletins on Ferris signal generators and other measuring equipment also available.

FERRIS INSTRUMENT CORPORATION

BOONTON • NEW JERSEY

Particle Sizer

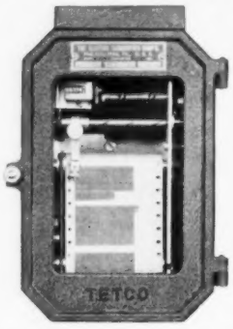
Designed for particle sizes below 44μ (325 mesh) and for factory use by untrained persons, Palo-Travis Particle Sizer employs a new sedimentation-rate method permitting determinations in about 2 hours, from samples of less than 5 g., with accuracy generally equal to that of expensive laboratory apparatus. Larger glass tube gives height of fall exceeding 1 m., above it is mixing chamber; below it the smaller sedimentation tube with illuminator and electric tapper at right and micrometer eyepiece at left. One man can operate several sizers at same time.—*Colloid Equipment Co., Inc., 50 Church St., New York City.*

Volt-ohm-milliammeter

Ranges of new "Jumbo Six-in-One Model 4922" volt-ohm-milliammeter are

said to "cover practically all applications of electrical measurements": A-c. and d-c. volts, 0/10/50/250/500/2500; d-c. microamperes, 0/500; d-c. milliamperes, 0/5/50/500; Resistance, 0/30 (8 ohms mid-scale), 0/10,000 (150 ohms mid-scale), 0/1 megohm (15,000 ohms mid-scale), and 0/10 megohms (150,000 ohms mid-scale); Decibels —10 to +15; a blocking condenser is provided so that the a-c. voltmeter may be used as an output meter. All ranges are guaranteed to accuracy within 2%, within an ambient temperature range of 50° to 90° F. Instrument incorporates a new type rectifier circuit said to withstand "twice the overload possible with any other type of rectifier circuit."—*The Hickok Electrical Instrument Co., 10514 DuPont Ave., Cleveland, Ohio.*

TETCO
Speed Recorder



Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced.

The Electric Tachometer Corp.
1358 Spring Garden St., Philadelphia, Pa.

NEW "ALNOR" PORTABLE PYROMETER

Shock Resisting, Floating Movement, Has 5" Mirrored Scale Metal Case.
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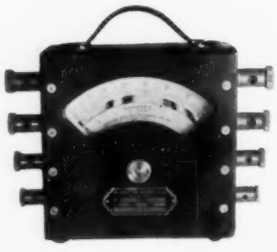
Multirange A. C. Ammeter



Entirely Self Contained—Meets Maximum Test Requirements

7 Ranges 2 to 200 Amperes
Weighs 5½ Pounds 5½" Scale
Accuracy Within 0.7%

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INCORPORATED
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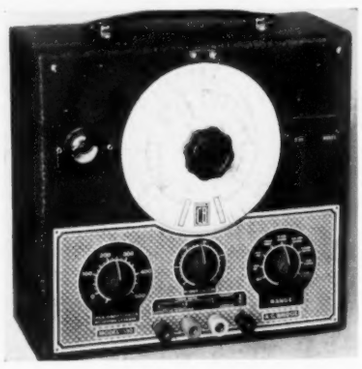
RHEOSTATS
Ask for Catalog No. 5
National Electric Controller Co.
5317 Ravenswood Ave., Chicago, Ill.

Direct-reading Hardness Tester

Outwardly, new direct-reading hardness testing machine presents same appearance as maker's previous machines but interior mechanism is said to be different both in arrangement and principle. Piston is of the ground, packless, self-guided type, is said to be "of generous proportions." There are no diaphragms. Operating mechanism is without a piston return spring. Test load thus is said to remain the same regardless of height of stroke. There is no exposed piping and all overflow is directly back into the reservoir. Work screw and screw support may be locked rigidly. Top of base, directly under test ball, is machined to provide footing for special fixtures if required. These fixtures may be interchanged "in a minute." Adjustment of both primary and test loads may be effected from outside of machine without disturbing anything else. Motor-driven pump is of rotary gear type; shaft is ball-bearing mounted. Ordinarily a standard 1/3-hp. 120-volt, 1725-r.p.m. ball bearing motor is supplied but since drive is by flexible coupling another motor may be substituted. Operating valve is connected to a foot treadle, leaving the operator's hands free. Direct-reading arrangement is without clutches, solenoids, contacts, etc.—*Detroit Testing Machine Co., 5135 Trumbull Ave., Detroit, Mich.*

A-c. Bridge

Automatic "good-bad" leakage indication of electrolytic condensers by "magic eye" is provided in new Model 130 a-c.



Bridge, incorporating three capacity ranges from 1μfd. to 100 mfds., and three resistance ranges from 10 ohms to 500 megohms, in addition to measuring power factor of electrolytic condensers from 0 to 50%, and transformer turns ratios from 0.01 to 100.—*Clough-Brengle Co., 2815 W. 19th St., Chicago, Ill.*

FLAME-OTROL

Protects Gas Fired Equipment Against Explosion

Affords positive protection under every conceivable operating condition for furnaces, ovens, heaters or boilers. Works with any kind of gas—flame fluctuation has no effect. Instantly shuts down furnace in case of flame failure. Also adapted to oil and pulverized coal fired units. COMPLETELY APPROVED AND LISTED BY ASSOCIATED FACTORY MUTUAL AND UNDERWRITERS LABORATORIES.

Further information Sent on request

PRICES FROM **$65**

WHEELCO INSTRUMENTS CO.
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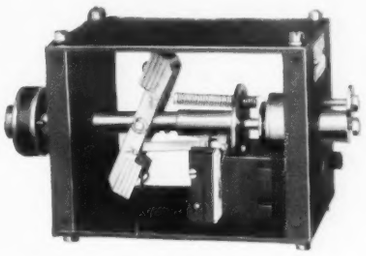
Centrifugal-speed Relay

New "Type GCR-10" centrifugal-speed relay for controlling rotating machinery between 70 and 4000 r.p.m. may be set to indicate either excessively high or low speeds or both, and for synchronous-speed indication. Feature is that it is adjustable in operation. Calibration within range may be made without stopping the machine. Relay may be mounted vertically or horizontally, will operate with clockwise or counterclockwise rotation. No current-carrying brushes and slip rings to service, sealed ball bearings require no lubrication. An insulated flexible coupling allows for driving shaft end play and misalignments, serves also as an insulator. Switches on stationary part are separately adjustable in position, and are readily interchangeable to provide either automatic or manual reset.—*Central Station Dep't, General Electric Co., Schenectady, N. Y.*



THE AC-ME RECORDING GRAVITOMETER

An Aid to Determination of Accurate Daily PLANT EFFICIENCIES when gas is used as fuel.

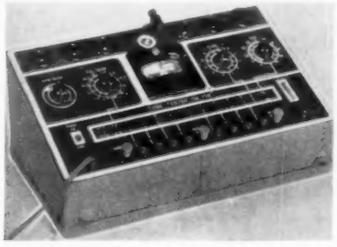
The Ac-Me Gravitometer contains no rotating parts and is compensated for temperature and barometric pressure variations.

Particulars given in catalog No. 22.

THE REFINERY SUPPLY CO.
631 E. 4th St. Tulsa, Oklahoma

Radio Tube Tester

Designed for simplicity of operation, new RCA Radio Tube Tester is available in two models: counter type, No. 156-A; and portable unit with carrying case. Tester can be operated with one finger: eleven push buttons released or retained automatically, roller chart for setting the various controls, and guide lines on control panel indicating the proper controls to be operated. Unit has six sockets (including one spare for future), tests all types of gas, ballast and battery tubes; tests 1" and 2" cathode-ray tubes for shorts and emissions; will discover noisy welds and circuit breaks in four-prong and octal-base ballast tubes. "Magic Eye" tuning indicator tubes may be tested for brilliance and for opening and closing of the eye. New instrument makes all tests according to RMA standards. Line voltage adjustment adapts unit for 100- to 125-volt line power; it is not necessary to set line voltage before inserting tubes in sockets. Power consumption is 25 watts, with one rectifier tube being used. Weight 14 lbs. Dimensions: 13½" long, 8" high, 5¾" deep.—*Parts Div., RCA Mfg. Co., Camden, N. J.*



TEJAX INDICATORS
for
ROTARY and SCREW MOTION

Panel Model

Accurate handwheel position indicators for the many applications requiring control by rotary or screw motion; regulating gates, rollers, variable speed equipment, shutters, valves, dampers, etc.

Precise settings are indicated on bold face visible dials, graduated as close as 1/100 of a turn, enabling close control and insuring more uniform results.

Variety of models with several finishes are furnished with hub sized for attachment as desired. Write for bulletin.

TEFFT-JACKSON, INC.
2 Allens Ave. Providence, R. I.

PYRO THE SIMPLIFIED OPTICAL PYROMETER

Self-contained, Direct-reading, Rugged and Fool-proof

Unique construction permits measuring temperature of minute spots, fast moving objects, or small streams. No correction charts—no accessories.
Available in new type with 3 direct-reading scales.

Stock Ranges: 1400° to 5500° F.

PYRO RADIATION PYROMETER
Ideal for boiler or other furnaces.

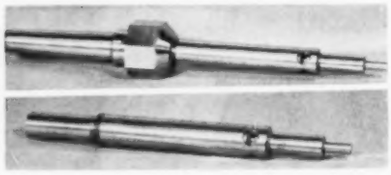
Does not require skilled operator. Stock ranges 1000° to 3600° F.

Write for special bulletins

THE PYROMETER INSTRUMENT CO.
103-107 LAFAYETTE ST., NEW YORK, N. Y.
311 ROSS ST., PITTSBURGH, PA.

Electric Center Finder

For use in production of master gages, dies, jigs, etc. and in experimental shops —where preliminary setting presents difficulties heretofore solved by computations or use of locating microscopes (and by employment of highly skilled men)



new Pierce-Bacon Center Finder is said to permit greater accuracy than conventional jig-borer microscope and this accuracy is independent of operator's skill or visual acuity. It is a hollow cylindrical tool of four sized sections containing dry cells and lamp visible through four holes in lower section. End or shankk section, ½" diam. × 1½" long, is inserted in chuck or sleeve. For jig borers a taper shank machine for the standard draw rods and having a hex. nut for centering the tool on its spindle is provided. The center of the center finder defines the actual center of the work spindle. When device must work from deep edges, accurately-sized disks may be pressed on the pilot unit. When contact with the work and instrument is established the light flashes on—this indication being said to be "supersensitive." Instrument can be used also in connection with ordinary lathe, miller, etc.— *R. Y. Ferner Co., 161 Devonshire St., Boston, Mass.*

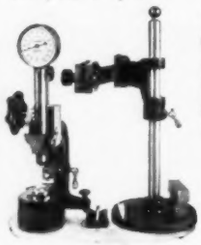
Predetermined-weight Scale

New light-weight scale for weighing operations requiring predetermined

weighing is said to permit unusual accuracy, registering immediately any variation of a fraction of an ounce; has a center tower mounting for the dial mechanism and two weighing counters. Unit sensitivity: indicator travels 1" to the ounce; ultimate sensitivity 1/64th oz.; capacity 5 lbs. A built-in carrying handle in top of center tower enables the scale (which weighs 13 lbs.) to be carried like a valise.—*Toledo Scale Co., 3216 Monroe St., Toledo, Ohio.*

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.



In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

Illustrated bulletins free.

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Magnet *Established 1924* Solenoid
Electrical Coil Winding Co.
2736 Saunders St., Camden, N. J.

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Flat Stationary or Moving Curved Surfaces

The "Alnor" Combination Pyrocon
Ideal for rolls, molds, plates, platens and plastic material temperatures.
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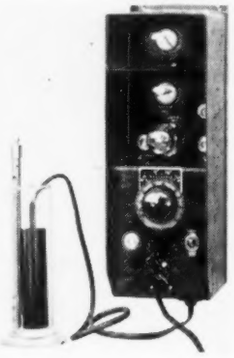
You may win a prize
Instrumentation Contest
See page 255

Continuous Analyzer For Feed-water, etc.

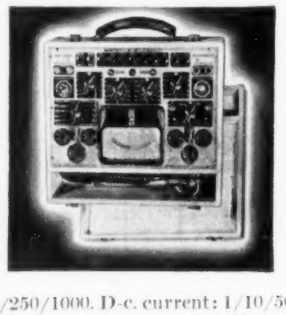
"Nalco Blinker" continuously indicates solids content in condensate, steam, feed or boiler water, or checks quantity of dissolved solids in any water containing from 1 p.p.m. to 700 grains per gallon (12,000 p.p.m. approx.). Water or condensed steam is passed through an electrode connected by wires to the Blinker which may be in laboratory, boiler room, etc. If connected to a continuous blow-



down line, instrument can be adjusted so that the upper light glows for too high concentrations and the lower for too low. Blinker measures conductivity. Temperature is "automatically taken care of by a fixed scale behind the rotating dial." Difference in conductivity, such as caused by an unusually high percentage of sodium chloride or hydrate is compensated for by electrode adjustments. Sensitivity of the lights to changes of solids is adjustable by means of a knob. *National Aluminate Corp., 6216 W. 66th Place, Chicago, Ill.*

Tube Tester

New "Series 900" push-button-operated Dynamic Mutual Conductance Tube Tester has following ranges: A-c. and d-c. voltage at 1000 ohms per volt:



10/50/250/1000. D-c. current: 1/10/50/250 milliamps and 10 amps. Resistance: 400 (20-ohms center) shunt method, 100,000 (800 center); 1 megohm (8000 ohms center) and 10 megohms (80,000 ohms center). Four decibel ranges from —10 to +55. Output ranges: 10/50/250/1000 volts. Paper capacitator leakage tests: neon method; provision for measuring electrolytic capacitor leakage directly in terms of current. Weight 12 lbs.; size 12¾" × 11½" × 6".—*Precision Apparatus Corp., 821 East New York Ave., Brooklyn, N. Y.*

Rawson Twin Multimeter

29 ranges in less space than any near equivalent combination—size 12" x 8" x 6"

RANGE OF MEASUREMENTS

D.C. 1 microampere to 1 ampere
20 microvolts to 1000 volts
A.C. (up to 3000 cycles)
2 milliamperes to 3 amperes
60 millivolts to 1000 volts

List Price $165.00

The Rawson measuring instruments are the only ones having two pivot movements whose weight is lifted from jewels when clamped for transit. Electrical clamping does not accomplish this purpose.

Special apparatus built to order

Rawson Electrical Instrument Company

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Representative: E. N. Webber
1313 W. Randolph St., Chicago, Ill.

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Self-Generating Photo-Electric ELEMENTS (Barrier Layer Cells)

Ultra-Sensitive
Permanently Stable
Unlimited Life

Great variety of sizes and shapes. Round Cells from 3/8" to 2 3/8" dia.
Unmounted or mounted in various styles of casings.
Visual Correction Filters available.

NEW: FOOT CANDLE METERS of unequalled sensitivity

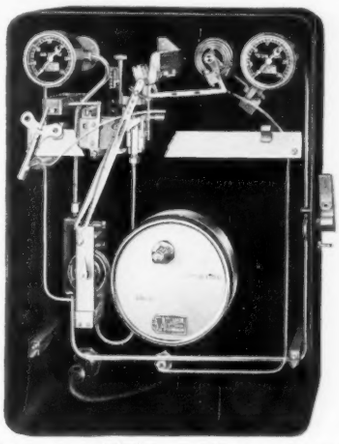
PHOTRIX
UNIVERSAL PHOTOMETER

Single-Cell Model:
0.05 ft.-cdl. per 1/16" division $57
Double-Cell Model:
0.005 ft.-cdl. per 1/16" division $100
Higher Sensitivity Models with multiple cells on order.

DR. F. LOEWENBERG
10 East 40th St. New York City

New Recorders and Recorder-controllers

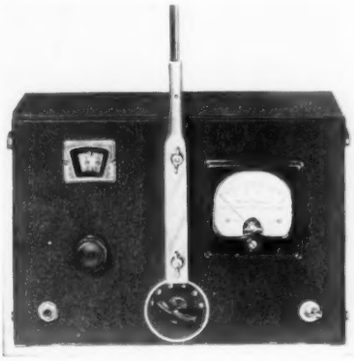
Maker announces a new line of "TAG" recorders and recorder-controllers with 10" and 12" charts; case is finished in black enamel and chromium. Features of new recording thermometer and pressure gage include interchangeable calibrated tube system that need be checked at one



point only; stainless steel pen-arm removed easily for cleaning or replacement; capillary fountain pen with draftman's split-nib; pen-arm movement supported by bearings at both ends. Including all these features, the new recorder-controller is offered in either "on-off" or throttling control model. The "on-off" model with simple non-adjustable flapper fits ordinary temperature control applications; the throttling model utilizes an adjustable calibrated flapper which provides sensitivity adjustment, permits adjustment of throttling range to coincide with any considerable apparatus lag.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Avenues, Brooklyn, N. Y.*

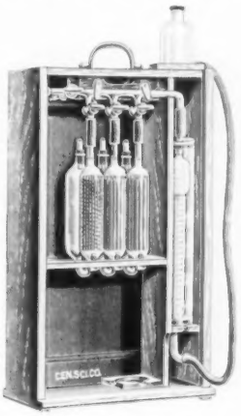
Field Strength Meter

New portable outfit for measurement of field intensity of antennas on frequencies from 1750 to 60,000 kc. employs a diode tube rectifier powered from a



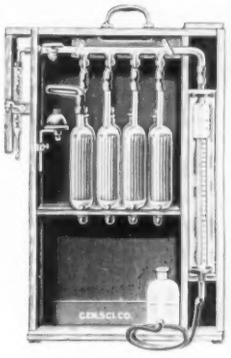
single dry cell mounted in the case. A wave change switch for six bands and a phone jack for monitoring are provided. Damped square-case instrument indicates relative radio frequency field. Field Strength Meter permits rapid measurement of the overall characteristics of radio transmitters as low as 2 watts.—*Radio Transceiver Labs., 8627 115th St., Richmond Hill, New York City.*

FLUE GAS ANALYZERS



20300 Orsat-Muencke, with 3 absorption pipettes for CO_2, CO and O_2 analysis

$40.50



20310 Orsat-Lunge with 4 absorption pipettes, for CO_2, CO, O_2 and H_2 analysis

$47.50

CENTRAL SCIENTIFIC COMPANY
SCIENTIFIC INSTRUMENTS CENCO LABORATORY APPARATUS
1700 IRVING PARK BOULEVARD, CHICAGO, ILL.

METAL INSTRUMENT PANELS

Specially Fabricated

Economically—Accurately—Speedily

Also

{ CABINETS ENCLOSURES } { CASES RACKS }

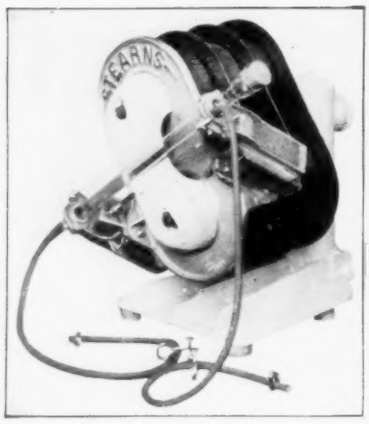
Any Metal Any Thickness Any Size Any Finish

Die Cost Can be Eliminated By Our Numerous Stock Dies

KARP METAL PRODUCTS CO.
INCORPORATED
129 - 30th Street Brooklyn, N. Y.

Magnetic Analyzer

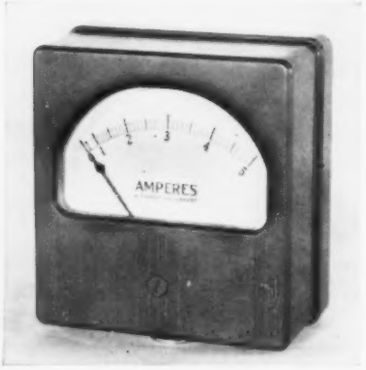
New vibro-magnetic-analyzer permits rapid determination of magnetic values in various ore slurry, supplementing or replacing chemical analysis methods; comprises a d-c. magnet and a magnetically vibrated test tube, this assembly being tiltable to any desired angle. Base



has rubber feet and under normal operation the unit is "practically noiseless." Vibration amplitude setting range is 0 to 3/16". Magnet strength also can be regulated. Pole faces of two types are furnished. A switchboard completes the equipment. Feed or concentrate samples containing up to 1g. of magnetic material can be accommodated. Twenty analyses an hour can be made. Where a-c. only is available, a rectifier can be furnished.—*Stearns Magnetic Mfg. Co., Milwaukee, Wis.*

Panel Instruments

New "37" line of panel instruments covers industrial and radio applications in a variety of forms, includes d-c., a-c., Rectox and thermocouple types, employs but two types of mechanisms: for d-c.



circuits and for Rectox and thermal types, permanent-magnet moving-coil; for a-c. circuits, repulsion iron vane. 750-volt rating corresponds to a test of 2500 volts between terminals and panel. Capacities range from as low as 20 microamps in moving-coil types, to self-contained ammeters of 30 amps and voltmeters of 200 volts. Among features are longer scales, flush and projection rectangular forms, and sealed gaskets making instruments dust- and moisture-proof.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

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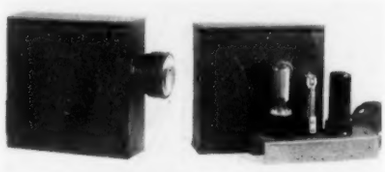
Universal Photometer

Two models of the new "Photrix" photoelectric light meter are announced. "Model A" (illustrated) is said to be one of the most sensitive portable light measuring instruments and the first instrument sensitive enough to distinguish between intensities in different parts of

a photographic negative while in an enlarger by scanning enlarged image on base board of enlarger. Any number of ranges is available by use of baffler or diaphragms, each cutting down by a definite factor the luminous flux incident on photocell. Most sensitive range (with entire surface of photocell exposed) is 2.5 ft.-candles full-scale. Knife-edge pointer permits reading to 0.01 ft.-candle. For higher sensitivities, multiple photocells are available: with a double cell, a full-range deflection can be obtained at 0.25 ft.-candle and sensitivity of 0.001 ft.-candle. A nine-cell frame (area 5" × 7") is so sensitive that it permits determining exposure times in micro-photography. "Model B" is similar in appearance, has three ranges, the most sensitive 12 ft.-candles full-scale. Both instruments employ "Electrocell" elements (see *Instruments*, Oct. 1935, page 272).—*Dr. F. Loewenberg, 10 E. 40th St., New York City.*

Photoelectric Control Outfits

Available in kit form or completely wired for operation, "LS-1" light source



units and "PC-1" photocell relay units operate on 110-volt 60-cycle a-c. supply. Light source is designed and constructed for 24-hr. operation, may optionally be furnished with infra-red filter for daylight operation. Its light beam will operate "PC-1" relay at 12 ft. (at 9 ft. with infra-red filter). Relay has set of normally-open and normally-closed contacts similar to s-p-d-t switch action. Palladium contacts will handle 3 amps. non-inductive load, 1.5 amp. inductive or 110 watts rating.—*Lipman Engineering Co., 415 Van Braam St., Pittsburgh, Pa.*

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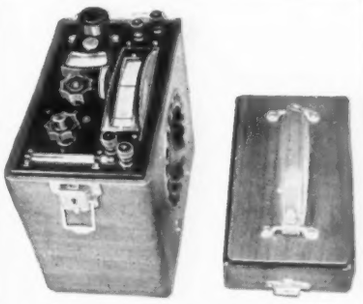
For industrial use, new Wilder Micro Projector has been designed for bench installation: 15" height above and 21" depth below bench surface. Its viewing

screen is 12" × 17" and its standard magnifications are 20×, 31¼×, 50×, 62½× and 100×. Optical system is a separate assembly, so mounted on body as to assure preservation of alignment. Photographs easily taken. Using horizontal glass table, most pieces are simply laid on table without fixtures. Every part is within reach of operator.—*R. S. Wilder Co., Waltham, Mass.*



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Designed for assuring correct performance of fluid-relay control systems, new Type 245 regulator comes in ¼" size. Body and caps are of cast aluminum; inner valve assembly, strainer and diaphragm back-up plate are of stainless steel; spring is cadmium-plated steel; diaphragm is of Duprene composition. Two unique features are said to be the integral strainer assembly, and relief valve built in diaphragm. Medium flowing through strainer area is said to be entirely cleansed of foreign bodies prior to passing through screen protecting inner valve assembly. Liquid separated is easily drawn off by bleed valve at bottom of unit. Inner valve seats in direction of flow; when outlet pressure reaches set pressure governed by spring, diaphragm lifts from mushroom head on the inner valve, dissipating any excess pressure into area above diaphragm and venting. Thus regulator is protected with a relief which is always set slightly in excess of control pressure. Regulator capacity is sufficient to handle four instruments or pilots.—*Hanlon-Waters, Inc., Box 1559, Tulsa, Okla.*

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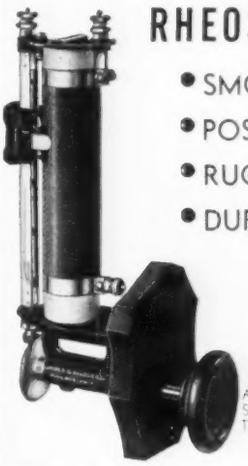

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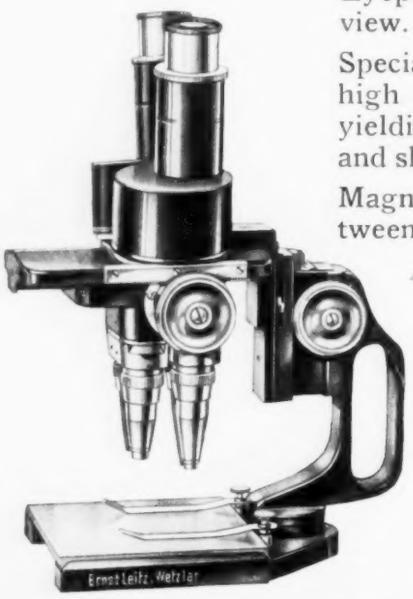

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Reports on Progress in Physics, Vol. IV (covering the year 1936). ALLAN FERGUSON, General Editor for THE PHYSICAL SOCIETY. The University Press, Cambridge, England, 1938. Cloth, 7 × 10 inches, 390 pages. Price 20s.

In reviewing the preceding volume we remarked: "This periodical gets better every year . . . is rather spotty . . . as a whole a meaty permanent reference . . . about 160,000 words . . . most authors have striven to prepare terse correlated abstracts rather than verbose essays . . ." These comments apply to Vol. IV, but we note a tendency to include reports which review older work in correct perspective before crisply summarizing the latest discoveries; and reports which outline the elements of specialized branches of physics for the benefit of non-specialists before going into little-known details. In both these respects there are four "reports" which qualify as masterpieces that will delight as well as edify the majority of *Instruments* readers:

The Measurement of Time, by H. Spencer Jones (the Astronomer Royal);

The Beginnings of the New Quantum Theory, by H. T. Flint;

Slow Neutrons, by P. B. Moon;

Electrolytes and Electrolysis, by R. W. Gurney.

To these reports we must add the first section of J. H. Awbery's report on Thermodynamics, entitled "Fundamental Principles": it compresses into fourteen pages the substance of an "introduction to thermodynamics" such as would ordinarily be published as a college textbook. It is the gem of Volume IV.

Recommending these five reports does not imply disparagement of other reports by other authors: these others, however, will please specialists more than they will please the average American worker in the average American physical laboratory. These other reports cover a wide range of subjects:

The Adsorption of Gases by Solids, by E. K. Rideal;

Surface Tension, by R. C. Brown;

Sound, by E. G. Richardson;

Supersonics in Relation to Molecular Constitution, by E. G. Richardson;

Heat, by R. W. Powell;

Refrigeration, by Ezer Griffiths;

Atomic Physics, by C. H. Collie;

The Charge of the Electron, by H. R. Robinson;

Experimental Electricity and Magnetism. Editor, L. Hartshorn: (1) The Breakdown of Insulating Materials, Electric Strength, by L. Hartshorn; (2) Measurement of Current at Radio Frequencies, by T. Iorwerth Jones; (3) Electrical Oscillations and Biological Materials, by W. H. Ward; (4) Frictional Electricity, by W. H. Ward;

Physical-optical Instruments and Materials, by F. Simeon;

Spectroscopy. Editor, W. Jevons: (1) Spectroscopic Methods of Chemical Analysis, by W. R. S. Garton; (2) Astronomical Spectroscopy, by A. Hunter; (3) Vacuum Spectroscopy, by R. W. B. Pearse; (4) Complex Atomic Spectra, by E. W. Foster; (5) Infra-red Spectra of Organic Molecules, by Lotte Kellner;

X-ray Analysis and Application of Fourier Series Methods to Molecular Structures, by J. M. Robertson;

Diamagnetic and Paramagnetic Anisotropy of Crystals, by Kathleen Lonsdale.

Wide as is this range of subjects, it is not complete. It is not designed to be complete. Nor does it have to be complete, because certain subjects were covered so exhaustively in Volumes II or III that the progress made in these fields during the intervening twenty-four or twelve months probably seems relatively insignificant. A case in point is the absence of a report on Photoelectricity—which probably was deliberately omitted because G. A. Boutry's outstanding report (the gem of Vol. III) is still timely and will continue to be up-to-date during the next three or four years if no "revolutionary" discovery is made.

Last year in our review of Vol. III we criticized some of its authors for neglecting to mention outstanding American work which had been re-

BOOK SHELF

ported in American engineering (rather than scientific) publications—and we cited examples. This year we note with pleasure that some of the Vol. IV authors notice that some important findings are written up exclusively in N.A.C.A. publications, in *Mechanical Engineering*, in *Industrial and Engineering Chemistry* and in other American publications outside of what might be called the highbrow circle. This should make the present volume more valuable to European workers—and even to American workers who take it for granted that all these reports are *designed* to be comprehensive.

Fairly comprehensive though some reports happen to be, this is not by design. Most of the authors—as writers, not as workers—are brilliant rather than thorough—and we mean this as a compliment: they don't go in for the indoor sport of combing every source and amassing a stack of references and finally turning out a wondrous report which is 100.00% complete but which reads like a telephone directory.

As we said of Vol. III last year: "No physical research laboratory is completely equipped if it lacks this volume and its precursors."

—M. F. BÉHAR (12.1)-**B**

Physics in Industry—Magnetism. The Institute of Physics, London, 1938. Cloth, 6⅛ × 9⅝ inches, 102 pages.

Latest developments in both the technical and the theoretical sides of magnetism are presented in a series of six papers published by the Institute of Physics following a conference held at the University of Manchester. In the foreword, W. L. Bragg, director of the National Physical Laboratory, points out that the theory of magnetism is now becoming well enough established to serve as a guide to further technical advances. This book conveniently ties together the current theories and available materials.

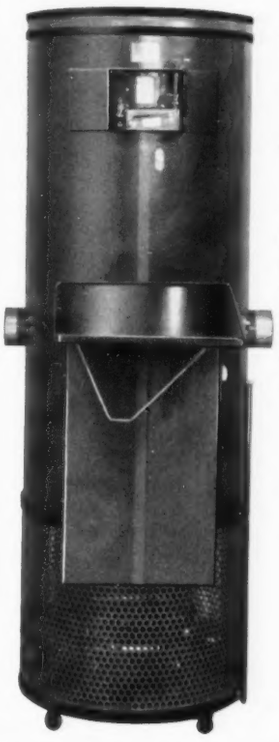
The first paper, "Magnetism and the Electronic Theory," sets up the basic conditions for magnetic properties in metals and alloys from consideration of electronic states. In the second paper, "Electrical Sheet Steel," the obstacles that prevent the attainment of maximum theoretical magnetic properties are discussed, with special reference to transformer sheet. Large grain size is shown to be necessary for best magnetic properties, but such mechanical requirements as strength and ease of punching thin sheets makes some compromise necessary. Possible improvement through increase in purity of the metal is discussed. Improvements in other commercial magnetic materials such as used in rotating machinery are considered in the third paper, "Influence of Materials on Design," pointing out the practical limitations to further increases in ratings and improvement in performance.

Saturation depends on chemical condition and is little affected by physical treatment, according to the author of the fourth paper, "Magnetization of Ferromagnetics." However, the manner of approach to saturation depends largely on internal stress conditions. Initial magnetization is closely related to conditions within individual grains. Therefore, the essential requirement for a high permeability is the reduction of internal strains, while for a high coercive force strains must be as large as possible.

A brief history of permanent magnet materials and the magnetic properties of available materials is included in the fifth paper on, "Permanent Magnets." In discussing uses for these alloys, attention is given to the requirements of the instrument field, and the advantages of the more recent types of alloys. X-ray studies of the Ni-Fe-Al alloys, reported in the sixth paper, demonstrate that the exceptional properties of this type of material arise from the extremely high strain to which the iron atoms are subjected following the partial precipitation heat-treatment.

—R. W. CARSON, *Consultant on Instrument Springs, Little Falls, N. J.*

(4.4)-**B**-



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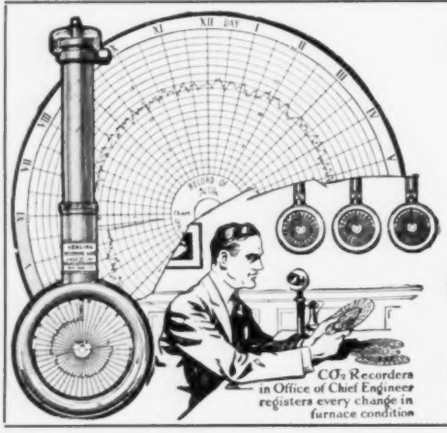

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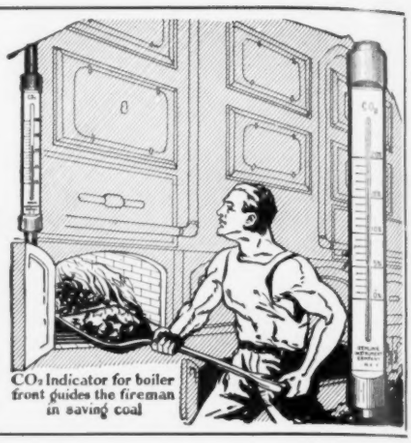

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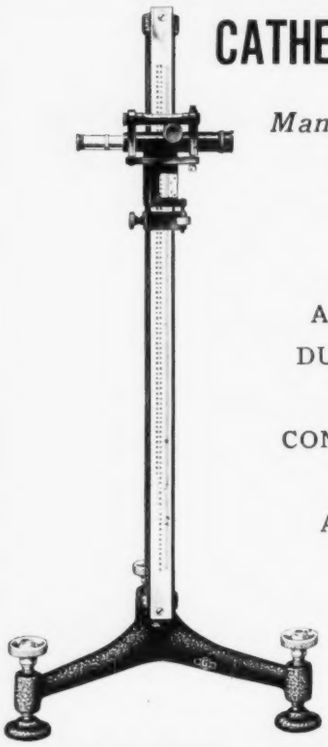

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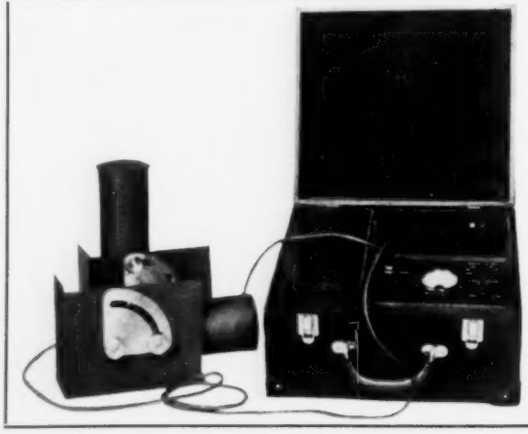

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